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REPORT ON

RESOURCE AND POTENTIAL RECLAMATION EVALUATION OF

SHY/6 STUDY SITE OTTER CREEK COALFIELD MONTANA 1978

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RESOURCE AND POTENTIAL RECLAMATION EVALUATION OF SHY/6 STUDY SITE OTTER CREEK COALFIELD, MONTANA

CONTENTS

	Page
Introduction	1
Purpose	1
Authority	1
Location	1
Climate	2
Physiography	4
Geology	5
Regional Geology	5
Site Geology	6
Investigation	6
Stratigraphy	7
Structure	8
Paleontology	8
Engineering Geology	8
Coal Resources	9
Coal Analyses	9
Estimation of Coal Resources	9
Land Classification	10
Description of the Land	10
Alluvial Soils	10
Colluvial Soils	10
Residual Soils	11
Description of Classes	11
Methods and Procedure	12
Results of Classification	12
Soil Inventory	13
Reclamation Potential	13

PLATES

	Follows Page
Plate 1- General Location Map	2
Plate 2- Geologic and Investigations Map	6
Plate 3- Geologic Log of DH78-101	6
Plate 4- Overburden Thickness Map	10
Plate 5- Semi-Detailed Land Classification	12
Plate 6- Topsoiling	12
Plate 7- Subsurface Material	12
Plate 8- Soil Survey Map	13

TABLES

Table 1- Potential Consumptive use of Moisture and Available Moisture-Native Grasses	2

TABLES (cont.)

	Follows Page
Table 2- Coal Analyses	10
Table 3- Coal Reserves, Overburden, Interburden Volume and Ratios, Acres & Tons Per Acre	10
Table 4- Land Classification Specifications	10
Tables 5 through 8- Erosion Evaluation and Soil Profiles	Appendix
Table 9-(8 sheets)- Laboratory Analyses	Appendix

PHOTOGRAPHS

Photographs 1 and 2 ---------- 4

RESOURCE AND POTENTIAL RECLAMATION EVALUATION OF SHY/6 STUDY SITE OTTER CREEK COALFIELD, MONTANA

INTRODUCTION

The nation's ever increasing need for energy has focused attention on the abundant low sulphur coal resources in the western states, primarily the Rocky Mountain and the Northern Great Plains regions, due to the abundance, ease of extraction, and the quality of the coal present. It is the responsibility of the Bureau of Land Management to assist in meeting the nation's energy demands, and at the same time, provide for reclaiming surface mined lands.

Purpose

This study will provide data for developing reclamation objectives at a potential coal leasing area. The site was selected to determine if existing data collected for the nearby Otter Creek Study Site (EMRIA No.1) could be correlated or projected throughout the Otter Creek Coalfield.

Authority

This report is prepared in accordance with Section 4 of the Agreement between the Bureau of Land Management and the Bureau of Reclamation dated May 7, 1974.

Location

The Shy/6 Site is located in Powder River County, about 6 miles (9.7 km) southeast of Ashland, Montana. The site includes all of Section 6, T. 4S., R. 45 E. It is 2.5 miles (4 km) southwest of the Otter Creek Study Site (EMRIA No.1) which was completed in 1975. Plate 1 shows the general location of all pre-1979 study sites in the Otter Creek Coalfield.

The Federal Government owns all coal deposits in the site. The surface is privately owned.

CLIMATE

The Shy/6 Study Site is in the Otter Creek geographical area which has a continental type climate. It is cold in the winter and warm in the summer. Large daily variations are common. Elevations at the site range from 3085 (940) to 3599 feet (1067 m). The Broadus weather station, at elevation 3030 feet (924 m), receives 14.2 inches (361 mm) average annual precipitation and Birney, at elevation 3190 feet (972 m), receives an average of 13.7 inches (348 mm) annually. Torrential rainstorms are common and unprotected soil surfaces may erode severely during these storms. These storms, though common, may not cover large areas. Hailstorms occasionally cross the area, but these weather extremes do not place the area in any particular type storm belt. About 53 percent of the precipitation falls as rain during the growing season. Growth of native grass is rapid during May and June which are the wettest months of the year. Precipitation data from the Otter weather station located 32 miles (51.5 km) southwest of this site follow:

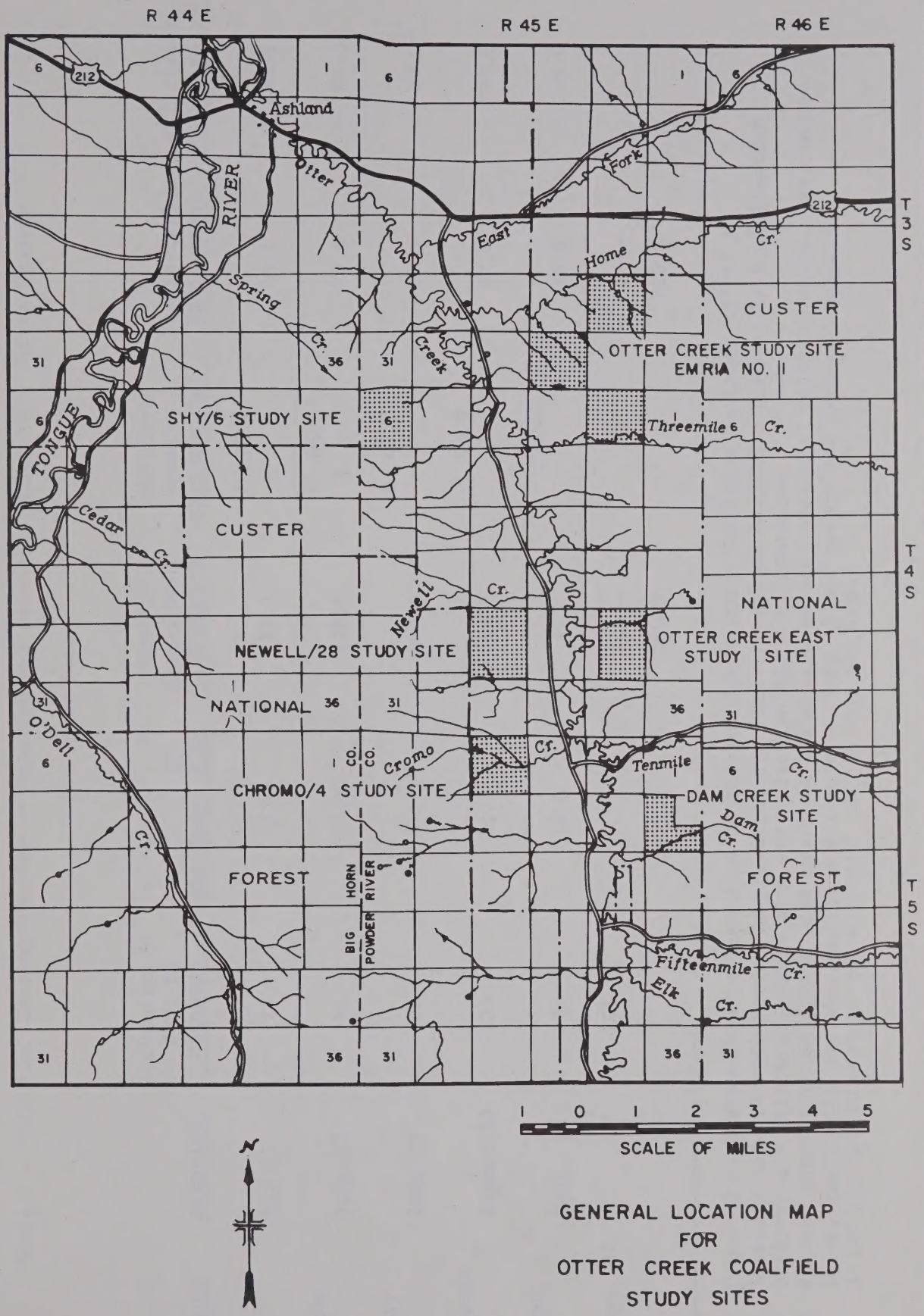
May	June	July	August	Sept.	Percent of Annual	Annual
2.51	3.30	1.32	1.26	1.69	53	19.1 1/ inches
63.8	83.8	33.5	32.0	42.9	53	485.1 millimeters

The elevation of the Otter station is 4000 feet (1219 m).

The frost-free period (32°F or 0°C) ranges from 108 days at Birney to 120 days at Broadus. The growing season for hardy grasses (28°F or -2.2°C) in average years begins May 10 at Birney and ends 131 days later on Sept. 19. Following the spring rains, July is hot, dry and windy with excessive evaporation and evapotranspiration rates. Humidity is low. During the months of June, July and August, about 32 days have a temperature of 74°F (23.3°C) or higher. Average monthly temperatures exceed 51°F (10.6°C) in May, June, July, August, September and October. July, with an average temperature of 74°F (23.3°C), is the hottest month and May and October,with 51°F (10.6°C), are the coolest growing season months.

The climate in the Otter Creek area in most years is suited for reclamation of surface mined land because the spring rains are generally adequate for establishing stands of native vegetation. The 13.7 (348) to 14.2 inches (361 mm) of precipitation received in average years meet the requirement of range vegetation which grows rapidly in the late spring and early summer. This moisture from natural precipitation is usually depleted by established native grasses in 6 to 8 weeks and the plants mature and become dormant. Consumptive use data in Table 1 show native grasses could use 22.5 inches (571 mm) of moisture if available; but it also shows that 13.9 inches (353 mm) or the average annual precipitation could be used by July 15. Table 1 prepared for the Otter Creek Study Site also represents the potential consumptive use in this site.

1/ The Otter station is several hundred feet higher than this study site. The apparent effect is an increase in the precipitation, especially during the nongrowing season.



GENERAL LOCATION MAP
FOR
OTTER CREEK COALFIELD
STUDY SITES

Multiply miles by 1.6093 to obtain kilometers

Table 1 - Potential Consumptive Use of Moisture and Available Moisture - Native Grasses [1/]

Shy/6 Study Site

Month	Midpoint	Accumulative Days to Midpoint	Air Temp. (°C)	Monthly Requirement Millimeters	Moisture Reserve Millimeters [2/]	Precipitation Millimeters	Difference Millimeters [3/]
May 4					+ 102.6		
	May 17	13	12.6	71.1		56.6	+ 88.1
June					+ 85.6		
	June 15	42	17.3	120.6		79.5	+ 47.0
July					+ 47.0		
	July 15	72	21.8	161.5		34.5	- 80.0 [4/]
August					- 80.0		
	August 15	103	21.0	140.2		27.4	- 192.8
Sept.					- 192.8		
	Sept. 13	131	14.6	77.5		30.5	- 239.8
Sept. 27		145					
				570.9		228.5	

1/ Computed by Blaney-Criddle Method using the Broadus Weather Station - Latitude 45°26' N.
2/ Moisture Reserve = Summation of precipitation (Oct. to April) = 128.3 x 0.80 = 102.6 millimeters
3/ Difference = Moisture Reserve plus precipitation minus moisture use
4/ Natural precipitation during most years is inadequate to meet potential moisture needs. In average years, the plants use the available moisture by July 15 and mature and become dormant.
Multiply millimeters by 0.03937 to obtain inches.

Reclamation of surface mined land is very difficult in areas that consistently receive 10 inches (254 mm) of precipitation or less each year. In this area, years that receive less than the average annual precipitation are not common. The Broadus station reported less than 10 inches (254 mm) only three times in the last 37 years and Birney only once in the last 21 years.

PHYSIOGRAPHY

The Shy/6 Study Site is in the unglaciated portion of the Great Plains Physiographic Province. Relief ranges from about 3085 feet (940 m) in the northeastern part of the section to about 3500 feet (1067 m) on a hill in the extreme southwestern corner of the section. The rugged topography is dominated by two narrow, steep sided valleys which cross the site from west to east. Numerous side gullies have eroded into the soft shales and sandstones, forming a dendritic drainage system. All drainage from the site is tributary to Otter Creek which flows northwestward into the Tongue River. Photographs 1 and 2 show typical terrain in the study area.

Photograph 1 - Shy/6 Study Site - Otter Creek Coalfield, Montana.
Panoramic view looking west toward DH78-101, which is near the white U.S.G.S. well casing in the right center of the photograph.
U. S. Bureau of Reclamation photograph 6/7/78

Photograph 2 - Shy/6 Study Site - Otter Creek Coalfield, Montana.
View looking northeast across Section 6 from near DH78-101.
U. S. Bureau of Reclamation photograph 6/7/78

GEOLOGY

Regional Geology

The Shy/6 Study Site is in the northern part of the Powder River Basin in southeastern Montana. This basin, a part of the unglaciated portion of the Great Plains Physiographic Province, is about 225 miles (363 km) long, extending from the Yellowstone River in Montana to the North Platte River in Wyoming. It is about 90 miles (145 km) in width, bounded on the west by the Bighorn Mountains and on the east by the Black Hills. Structurally, the basin is an asymmetrical syncline with a northwestward trending axis. An estimated 18,000 feet (5486 m) of sediments overlie the basement complex in the deepest part of the basin north of Glenrock, Wyoming.

The geologic history of the area since Precambrian time includes periods of deposition, deformation, and erosion. During the Paleozoic and Mesozoic Eras, a sequence of carbonates, sandstones, and shales was deposited throughout Montana and Wyoming. Thickness of these sediments on the west side of the basin varies from 9,000 feet (2743 m) near Yellowtail Dam to 11,500 feet (3505 m) near Buffalo, Wyoming. About 6,500 feet (1981 m) of Paleozoic and Mesozoic sediments are present in the Black Hills area on the east side of the basin.

The area was relatively stable during these periods with deposition usually occurring in a marine environment. Deformation of strata began with the Laramide Revolution near the close of the Mesozoic Era (Late Cretaceous), at which time mountain masses such as the Bighorns and Black Hills were uplifted. Uplift continued throughout Paleocene and gradually ended in Eocene Time. Materials stripped from the mountains were deposited in fans or sheets across the basin floors, gradually burying the flanks of the mountains in their own debris. By the middle of the Cenozoic Era, the basins were largely filled and the mountains peneplained. In Pliocene time, a broad regional uplift occured and continued intermittently into Pleistocene time. This uplift raised the previously developed peneplain surface to elevations of about 10,000 feet (3048 m) in the Bighorn Mountains. Streams rejuvenated by the uplift excavated the basins and exhumed the buried mountain masses.

Today, Precambrian rocks are exposed in the cores of the Black Hills and Bighorn Mountains. These rocks are surrounded by sediments of Paleozoic and Mesozoic Age. The central part of the basin is filled with Cenozoic (Tertiary) sediments.

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Site Geology

Investigations

Previous geologic investigations have been conducted in the general area by the U. S. Geological Survey and the Montana Bureau of Mines and Geology. A list of relevant maps and publications follows:

1. U.S.G.S. Bulletin 1072-J - Reconnaissance Geology of the Birney-Broadus Coal Field, Rosebud and Powder River Counties, Montana.

2. U.S.G.S. Miscellaneous Field Studies Map MF-802 - Willow Crossing Quadrangle, Montana.

3. U.S.G.S. Miscellaneous Field Studies Map MF-807 - Fort Howes Quadrangle, Montana.

4. U.S.G.S. Miscellaneous Field Studies Map MF-814 - Browns Mountain Quadrangle, Montana.

5. U.S.G.S. Miscellaneous Field Studies Map MF-817 - King Mountain Quadrangle, Montana.

6. Montana Bureau of Mines and Geology Bulletin 69 - Strippable Coal Deposits on State Land, Powder River County, Montana.

7. Montana Bureau of Mines and Geology Bulletin 91 - Quality and Reserves of Strippable Coal, Selected Deposits, Southeastern Montana.

Geologic investigations were conducted at the Shy/6 Study Site by the U. S. Bureau of Reclamation during June of 1978. Investigations included mapping the surface geology and drilling one core hole. Drill cores were tested by the U.S.B.R. Soils Laboratory for suitability in reconstructed profiles. Results of the tests are graphically shown on the geologic log. Detailed geologic mapping on a scale of 1 to 12,000 was done in the field on aerial photographs. The data were transferred to a topographic map and are shown on Plate 2. A detailed geologic log for Drill Hole 78-101 is included in this report (Plate 3).

Core drilling was performed using a Failing Model 314 rotary drill rig with an "H" series wire line core barrel. Water from Otter Creek was used as the drilling fluid. Test results conducted by the U.S.B.R. Soils Laboratory in Miles City, Montana, indicated that the total dissolved solids in the water supply was about 900 parts per million (900 mg/1).

EXPLANATION

PALEOCENE

FT. UNION FORMATION (TONGUE RIVER MEMBER) – Interbedded shale, siltstone, sandstone and coal.

CLINKER – Altered shale, siltstone and sandstone of the Fort Union Formation produced by burning of the Knoblock coalbed.

— A — A through G – Coalbeds

A – 2 to 2.5 ft. of coal. Corresponds to a local bed of USGS Miscellaneous Field Studies Map MF-802.

B – 2 to 3 ft. of coal. Corresponds to Cache bed of USGS Miscellaneous Field Studies Map MF-802 and "C" bed of Chromo/4 Study Site.

C – 0.5 to 1.5 ft. of coal and carbonaceous shale.

D – 1 to 1.5 ft. of coal. Corresponds to "D" bed of USGS Miscellaneous Field Studies Map MF-802.

E – 1 to 1.5 ft. of coal. Corresponds to "C" bed of USGS Miscellaneous Field Studies Map MF-802.

F – 1 to 2.5 ft. of coal. Corresponds to Sawyer 1 bed of USGS Miscellaneous Field Studies Map MF-802.

G – 1 to 2.5 ft. of coal. Corresponds to Sawyer 2 bed of USGS Miscellaneous Field Studies Map MF-802.

NOTE

"F" and "G" beds probably correspond to "A-C" beds of Otter Creek Study Site (EMRIA #1) and "F" beds of Chromo/4 and Newell/28 Study Sites.

DH 78-101 — USBR Drill hole

SH 7055 — Drill hole from USGS Miscellaneous Field Studies Map MF-802

NOTE

Elevations and distances measured in feet. Multiply feet by 0.3048 to obtain meters.

1000 0 1000 2000 3000

SCALE OF FEET
C.I. = 20'

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

SHY/6 STUDY SITE
OTTER CREEK COALFIELD-MONTANA

GEOLOGIC AND INVESTIGATIONS MAP

GEOLOGY L. PARISH — SUBMITTED
DRAWN L.E. ALLSOP — RECOMMENDED
CHECKED — APPROVED

BILLINGS, MONTANA SEPTEMBER 1978 | 1305-600-160

SHEET. 3 ... OF. 4 ...

STATE. Montana

ROM HORIZ.). Vertical

D BY.

CLASSIFICATION AND PHYSICAL CONDITION

F. 4.. HOLE NO.. 78-101 .....

Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET. 4 ... OF. 4 ...

FEATURE. Shy/6 Study Site Otter Creek Coalfield ... PROJECT. Work Order 003 ... STATE. Montana

HOLE NO. 78-101 LOCATION. 1900' N. & 1700' W. of SE Corner, Sec. 6, T. 4 S., R. 45 E. GROUND ELEV. 3255+ DIP (ANGLE FROM HORIZ.) Vertical

BEGUN. 6/13/78 ... FINISHED. 6/21/78 ... DEPTH OF OVERBURDEN — TOTAL DEPTH. 314.5 ... BEARING.

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED. 226.0 6/21/78 (3029.0) ... LOGGED BY. Taucher ... LOG REVIEWED BY.

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM	SOILS ANALYSIS SAMPLE DEPTH (FEET) TO	SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Hole at 314.5' 6/21/78. 6" Cs at 3.2'. 315.0' of 2" pipe in hole (perforated 220.0 to 280.0'). Put sand and gravel in hole. Pulled casing. Moved rig.		100						2952.6	302.4			
								2950.0	305.0			
		85										
	310								310			
		100						2940.5	314.5			
	320								320			
	330								330			
	340								340			
	350								350			
	360								360			
	370								370			
	380								380			
	390								390			

EXPLANATION

CORE LOSS

CORE RECOVERY

Type of hole ..... D = Diamond, H = Hoystallite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

NOTE
Multiply feet by 0.3048 to obtain meters

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

SHY/6 STUDY SITE
OTTER CREEK COALFIELD-MONTANA

GEOLOGIC LOG OF DH 78-101

GEOLOGY G TAUCHER SUBMITTED
DRAWN RECOMMENDED
CHECKED APPROVED

BILLINGS, MONTANA AUGUST 1978 1305-600-161

Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 4

FEATURE Shy/6 Study Site Otter Creek Coalfield PROJECT Work Order 003 STATE Montana

HOLE NO. 78-101 LOCATION 1900' N. & 1700' W. of SE Corner, Sec. 6, T. 4 S., R. 45 E. GROUND ELEV. 3255± DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 6/13/78 FINISHED 6/21/78 DEPTH OF OVERBURDEN — TOTAL DEPTH 314.5 BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 226.0' 6/21/78 (3029.0) LOGGED BY Taucher LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	BOULD ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Moved equipment from Newell/28 Site. Rx drive sample 0 to 3.0'; Fishtail 3.0 to 11.0'. Hq wireline 11.0 to 44.5'. 6" Cs set to 3.2'. 100% water return. Hole at 44.5' 6/14/78. 6" Cs at 3.2'. W.L. at 11.3'. Hq wireline 44.5 to 103.8'. 100% water return.		100 Wash 85 71 100 100 80 100 95 100 100	#1 3.0	24.0 #2 24.0 44.2 #3 44.2 69.0 #4 69.0 94.0				3252.0 3210.8 3161.0	3.0 44.2 94.0			FORT UNION FORMATION—PALEOCENE 0–3.0 SANDY SILTSTONE: Yellow-brown; oxidized; moist; soft; cuts easily with knife; highly weathered; few roots 0 to 0.6'; laminated; slight plasticity; trace of fine sand (ML-CL). 3.0–44.2 SHALE WITH COAL: Medium to dark gray, plastic, carbonaceous shale (trims easily with knife) 3.0 to 16.4' with broken coal 11.4 to 11.6 and 16.2 to 16.4'; medium hard weakly cemented (weak HCl reaction), thin-bedded (shaley) light gray, fine grain sandstone 16.4 to 19.0'; dark gray, plastic shale (trims by knife with some difficulty) cut by numerous slickensides 19.0 to 21.0' with broken coal 19.0 to 20.0'; medium gray, moderately plastic silty shale (trims by knife with some difficulty) 21.0 to 32.0'; broken, hard coal 32.0 to 32.3'; medium to dark gray, plastic shale (trims by knife with some difficulty) 32.3 to 44.2' with very hard silty limestone 38.2 to 39.7 and 43.5 to 44.2'; moist; most shales air slake; core lengths up to 24". 44.2–94.0 SANDY SHALE GRADING TO SHALEY SANDSTONE: Alternating laminations and thin beds of medium gray, silty, moderately plastic, firm (trims by knife with some difficulty) shale and light gray, very fine grain, uncemented silty sandstone (crushes between fingers). Shale is about 70% of sample near top and decreases to about 50% of sample near bottom; bedding is horizontal to 70°; appears crossbedded with dips up to 15° between 70 and 94'; very hard silty limestone 66.3 to 66.6 and 67.5 to 67.9'; sandy laminations contain small amount of calcium carbonate; moist; core lengths up to 24". 94.0–167.5 SHALEY SANDSTONE: Alternating laminations and thin beds of light gray, fine grain, uncemented sandstone (crushes easily between fingers) and medium gray, moderately plastic silty shale (trims easily with knife); sandstone is about 60% of sample; sandy laminations contain very small amounts of calcium carbonate; very hard silty limestone 98.0 to 101.0 and 160.5 to 160.8'; ¼" coal at 139.0'; crossbedded with dips up to 15°; moist;

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole . . . D = Diamond, H = Heystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . . . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 4

FEATURE Shy/6 Study Site Otter Creek Coalfield PROJECT Work Order 003 STATE Montana

HOLE NO. 78-101 LOCATION 1900' N. & 1700' W. of SE Corner, Sec. 6, T. 4 S., R. 45 E. GROUND ELEV. 3255± DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 6/13/78 FINISHED 6/21/78 DEPTH OF OVERBURDEN — TOTAL DEPTH 314.5 BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 226.0' 6/21/78 (3029.0) LOGGED BY Taucher LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	BOULD ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Hole at 103.8' 6/15/78. 6" Cs at 3.2'. W.L. at 17.4'. Hq wireline 103.8 to 163.8'. 100% water return. Hole at 163.8' 6/16/78. 6" Cs at 3.2'. W.L. at 33.0'. Hq wireline core 163.8 to 223.0'. 100% drill water return.		100 100 98 100 98 100 100 100 100 98	#5 94.0	119.0 #6 119.0 144.0 #7 144.0 167.5 #8 167.5 195.0				3087.5	167.5			core lengths up to 24". 167.5–220.5 SANDSTONE: Light gray; moist; very fine grain; clean; uniform; uncemented; crushes easily between fingers; bedding not generally discernible but where present is cross-bedded; carbonaceous laminations 181.0 to 183.0, 189.0 to 189.3, and 215.5 to 216.3'; becoming more firm and shaley 219.0 to 220.5'; core lengths up to 18". 220.5–287.5 COAL: Black; moist to wet; dull to metallic sheen; only small amount of coal visible for inspection as it was sampled in field; sample remaining was badly broken. 287.5–299.5 SANDSTONE AND SHALEY SANDSTONE: Light gray; firm (difficult trimming by knife) thin-bedded, shaley, fine grain sandstone 287.5 to 293.0'; soft plastic shale 293.0 to 293.2'; light gray, fine grain, weakly cemented sandstone (crushes easily between fingers) 293.2 to 299.5'; moist to wet; core lengths up to 24". 299.5–302.4 SHALE AND COAL: Shale is dark gray, plastic, firm (cuts by knife with difficulty), and is broken by numerous highly polished slickensides at various angles; coal is black, broken, and dull and occurs at 299.5 to 300.3, 300.6 to 301.0, and 302.0 to 302.2'. Core lengths up to 6"; moist. 302.4–305.0 SHALEY SANDSTONE: Light gray; moist; firm (difficult trimming by knife); fine grain shaley sandstone; laminated; moderate HCl reaction; core lengths up to 12". 305.0–314.5 SILTY SHALE: Light to medium gray; moist; hard (difficult trimming by knife); moderate HCl reaction; bedding not readily discernible; core lengths up to 14".

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole . . . D = Diamond, H = Heystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . . . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 4

FEATURE Shy/6 Study Site Otter Creek Coalfield PROJECT Work Order 003 STATE Montana

HOLE NO. 78-101 LOCATION 1900' N. & 1700' W. of SE Corner, Sec. 6, T. 4 S., R. 45 E. GROUND ELEV. 3255± DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 6/13/78 FINISHED 6/21/78 DEPTH OF OVERBURDEN — TOTAL DEPTH 314.5 BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 226.0' 6/21/78 (3029.0) LOGGED BY Taucher LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	BOULD ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Hole at 223.0' 6/19/78. 6" Cs at 3.2'. W.L. at 56.0'. Washed core in hole from 193 to 223'. Hq wireline 223.0 to 273.0'. 100% water loss at 226.0'. Difficulty in recovering coal. Probably washing away. Coal samples 223.0 to 233.0, 233.0 to 238.0, 238.0 to 243.0, 243.0 to 253.0, 253.0 to 260.0, 260.0 to 264.0, and 264.0 to 273.0'. Hole at 273.0' 6/20/78. 6" Cs at 3.2'. W.L. at 226.0'. Hq wireline core 273.0 to 314.5'. Total water loss. Coal sample 273.0 to 278.0, 278.0 to 283.0, and 285.0 to 287.5'. Bailed hole. Set 315.0' of 2" diameter plastic pipe in hole (includes 2' stickup). Pipe perforated 220.0 to 280.0'.		100 100 50 100 25 80 67 75 48 100 100 100	#9 195.0	220.5 #10 287.5 299.5				3034.5 2967.5 2955.5	220.5 287.5 299.5			

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole . . . D = Diamond, H = Heystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . . . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 4 OF 4

FEATURE Shy/6 Study Site Otter Creek Coalfield PROJECT Work Order 003 STATE Montana

HOLE NO. 78-101 LOCATION 1900' N. & 1700' W. of SE Corner, Sec. 6, T. 4 S., R. 45 E. GROUND ELEV. 3255± DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 6/13/78 FINISHED 6/21/78 DEPTH OF OVERBURDEN — TOTAL DEPTH 314.5 BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 226.0' 6/21/78 (3029.0) LOGGED BY Taucher LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	BOULD ANALYSIS SAMPLE DEPTH (FEET) FROM	TO	SUITABILITY FOR RECONSTRUCTED PROFILE SUITABLE	LIMITED SUITABILITY	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Hole at 314.5' 6/21/78. 6" Cs at 3.2'. 315.0' of 2" pipe in hole (perforated 220.0 to 280.0'). Put sand and gravel in hole. Pulled casing. Moved rig.		100 85 100						2952.6 2950.0 2940.5	302.4 305.0 314.5			

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole . . . D = Diamond, H = Heystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . . . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

NOTE:

SUITABILITY OF BEDROCK FOR RECONSTRUCTED PROFILES

SUITABLE- Can be used at or near the surface
LIMITED SUITABILITY- Should be placed in subsoil
UNSUITABLE- Should be buried below primary root zone

Drill core analysis shown on Table 9, sheet 8 of 8 in Appendix.

NOTE
Multiply feet by 0.3048 to obtain meters

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
SHY/6 STUDY SITE
OTTER CREEK COALFIELD-MONTANA

GEOLOGIC LOG OF DH 78-101

GEOLOGY S. TAUCHER SUBMITTED
DRAWN RECOMMENDED
CHECKED APPROVED

BILLINGS, MONTANA AUGUST 1978 1305-600-161

Stratigraphy

The Fort Union Formation of Paleocene Age underlies the entire area. It is divided into the Tullock, Lebo and Tongue River Members. The Tullock and Lebo Members are not discussed in this report as they are not exposed and were not encountered in drilling. Except for alluvium, only sediments in the lower part of the Tongue River Member are involved in the study area. The upper part of the Tongue River and younger rock have been stripped away by erosion. Brief descriptions of the Cenozoic sediments involved in the site follow:

Fort Union Formation (Paleocene)

Tongue River Member - pale olive to yellowish gray sandstone, siltstone, shale, carbonaceous shale and coal with thin lenticular calcareous or siliceous cemented concretions. Unweathered samples vary from light to dark gray in color. Poorly silicified, fragmented tree trunks and soft, calcareous shell fragments are common in zones. Sandstones, even though uncemented, tend to be resistant in outcrops. Shale and siltstone zones generally form slopes below sandstone ledges. Coal and carbonaceous beds are generally traceable over large areas. Conversely, correlation of clastic sediments over short distances is difficult due to variation in bedding thicknesses and lithologic changes. Tongue River sediments were deposited in a continental environment which included swamps conducive to the production of coalbeds. Thickness of this member varies from 1150 (351) to 1900 feet (579 m) in the Montana portion of the Powder River Basin.

One striking feature in the Tongue River Member is the resistant clinker zones that cap ridges or armor valley walls. The clinker, which is fused or baked rock, was produced by the burning of underlying coalbeds along their outcrops. In places where the heat was sufficiently intense, the clinker has been fused to a dark gray, lightweight rock similar in appearance to vesicular basalt. Near the outer edge of thermal metamorphism, the rock is disoriented, baked and red to orange in color. Alteration of the overlying material is roughly proportional to the original thickness of coal that has burned. A coalbed 20 feet (6 m) thick will produce clinker zones 40 (12) to 60 feet (18 m) thick. The clinker is highly permeable and locally supplies water for springs and wells.

Clinker produced from burning of the Knoblock coalbed covers about 34 acres (13.8 hectares) in the northeastern corner of the study site.

Only the Knoblock coalbed is of economic significance at the Shy/6 Study Site. It thins and splits into several benches southward from the Otter Creek Study Site, EMRIA No.1 and the Shy/6 Study Site. At the Otter Creek Study Site the coalbed averages about 61 feet (18.6 m). At the Shy/6 Study Site it is 67 feet (20.4 m) thick in U.S.B.R. Drill Hole DH78-101. At the Otter Creek East Site, a distance of 3 (4.8) to 4 miles (6.4 km) south of the Otter Creek Study Site, it splits into an upper and lower bench, 45 (13.7) and 17 feet (5.2 m) thick, respectively.

Across the valley, a mile (1.6 km) west of the Otter Creek East Site, at the Newell/28 Study Site, the Knoblock is also split into two benches. The upper averages about 38 feet (11.6 m) thick and the lower about 13.5 feet (4.1 m) thick. At the Chromo/4 Site, about a mile (1.6 km) south of the Newell/28 Study Site, the Knoblock splits into five main benches. In descending order, they are about 6, 26, 7, 2 and 10 feet (1.8, 7.9, 2.1, 0.6, and 3.1 m) thick. At the Dam Creek Site, about 2.5 miles (4 m) southeast of the Chromo/4 Study Site, the upper bench of the Knoblock coal is about 24 feet (7.3 m) thick and geologic data in the Montana Bureau of Mines and Geology Bulletin 91 indicate that lower benches of the Knoblock are insignificant. Plate 1 shows the locations of all study sites along Otter Creek.

Alluvium (Holocene)- deposits of clay, silt, sand and gravel that cover valley floors of Otter Creek and its tributaries. Gravels are generally composed of clinker or hard shale and sandstone fragments. The deposits are up to 20 feet (6.1 m) thick.

Structure

Sediments at the Shy/6 Study Site and in the surrounding Otter Creek Coalfield are generally flat lying with minor folding evident on the surface and on subsurface contour maps constructed using drill hole information. Some of the structural irregularities may be of a depositional nature while others may be due to differential compaction of the underlying strata.

Small local faults exist in the area as indicated by slickensides encountered in the drill core. They are generally restricted to weak, plastic, carbonaceous shales immediately above or below coalbeds. Displacement along the fractures could not be determined but probably does not exceed 5 feet (1.5 m). No faulting was observed during surface mapping.

Paleontology

Occasional poorly silicified tree fragments and pieces of unidentified calcareous shells were found on the surface area. However, nothing of significance was observed.

Engineering Geology

Engineering property tests were not conducted on bedrock samples from the Shy/6 Study Site. However, physical properties of these sediments should be similar to the results obtained for Fort Union samples at the Otter Creek Study Site (EMRIA Report No.1) by the U. S. Geological Survey. Shear strengths of the materials are low, especially in a saturated condition. Slides could easily develop adjacent to high walls in surface mines, especially along beds of weak, plastic, carbonaceous shales which are typically cut by inherent slickensides. Adequate drainage should be insured to relieve porewater pressures in the overburden as mine excavations progress.

Saturated alluvial deposits and uncemented siltstones and fine grain sandstones will readily erode and flow into excavations. This problem is occasionally encountered in drilling when the walls of holes continue to collapse and slough. Depth of excavation below the water table will be limited until these materials are unwatered.

Excavation slopes will vary considerably between mine sites and will depend upon exposure time, moisture conditions, materials types and depth of cut. Detailed engineering studies of the overburden will be required at each location for use in determination of designed slopes.

Studies conducted at the Otter Creek Study Site indicate that disturbed overburden (spoil banks and piles) should have slopes not greater than 4 to 1 with berms of 50 (15.2) to 100 feet (30.5 m) in width designed on the slope surface.

Coal Resources

Coal Analyses

Proximate, ultimate, Btu and sulfur forms analyses were completed by Northern Testing Laboratories in Billings, Montana, on a composite sample from DH78-101 between depths of 220.5 (67.2) and 287.5 feet (87.6 m). Test results are shown on Table 2. Results indicate that the coal is Subbituminous C rank with a heat value of 8485 Btu (15273 Kilogram-calories/kilogram) as received. The ash and sulfur contents as received are 6.25 and 0.23 percent, respectively.

Estimation of Coal Resources

The term "coal resources" is defined as the estimated quantity of coal that is currently or potenially economically mineable. Resource estimates have been prepared for the Shy/6 Study Site using standard procedures and are presented on Table 3.

The quantities shown are categorized as demonstrated resources and are the sum of measured and indicated resources. They contain coal for which estimates of rank, quality and quantity are known and coal for which estimates have been at least partly computed using reasonable geologic projections.

Table 3 shows coal reserves and overburden ratios for the Knoblock coalbed at the Shy/6 Study Site. It is a single bed 67 feet (20.4 m) thick- not split by numerous lenses of interburden as in other Otter Creek Study Sites further south.

Nearly 67 percent of the 582 acres (235 hectares) within the study site that contain the Knoblock coalbed are covered with 200 feet (61 m) or more of overburden. This area is composed of 210 acres (85 hectares) covered with 200 (61) to 250 feet (76.2 m) of overburden and 178 acres (72 hectares) with over 250 feet (76.2 m).

Table 3 divides the coal reserves into quantities covered by set ranges of overburden thickness. The overburden thickness contours are shown on Plate 4.

Stripping ratios were calculated for each set range of overburden thicknesses and are shown on Table 3.

LAND CLASSIFICATION

Land classification is a systematic appraisal of lands for a specific purpose. In this classification, lands were grouped in classes 1, 2, 3 or 6 based on their physical and chemical properties that related to their use for plant media in reclaiming surface mined land. Specifications are on Table 4.

Description of the Land

The principal natural land bodies consist of residual soils. There are small tracts of colluvial and alluvial soils along natural drains and footslopes. Within each soil type there is a range of physical and chemical properties. Alluvial soils are the most uniform and residual soils are the most diverse. The principal land condition represented by each soil group is described separately.

Alluvial Soils

The alluvial soils in this site are along the channels of small intermittent upland natural drains. Surface gradients range from 0 to 6 percent. The vegetative cover is largely mid and short grasses with scattered big sage and a few forbes.

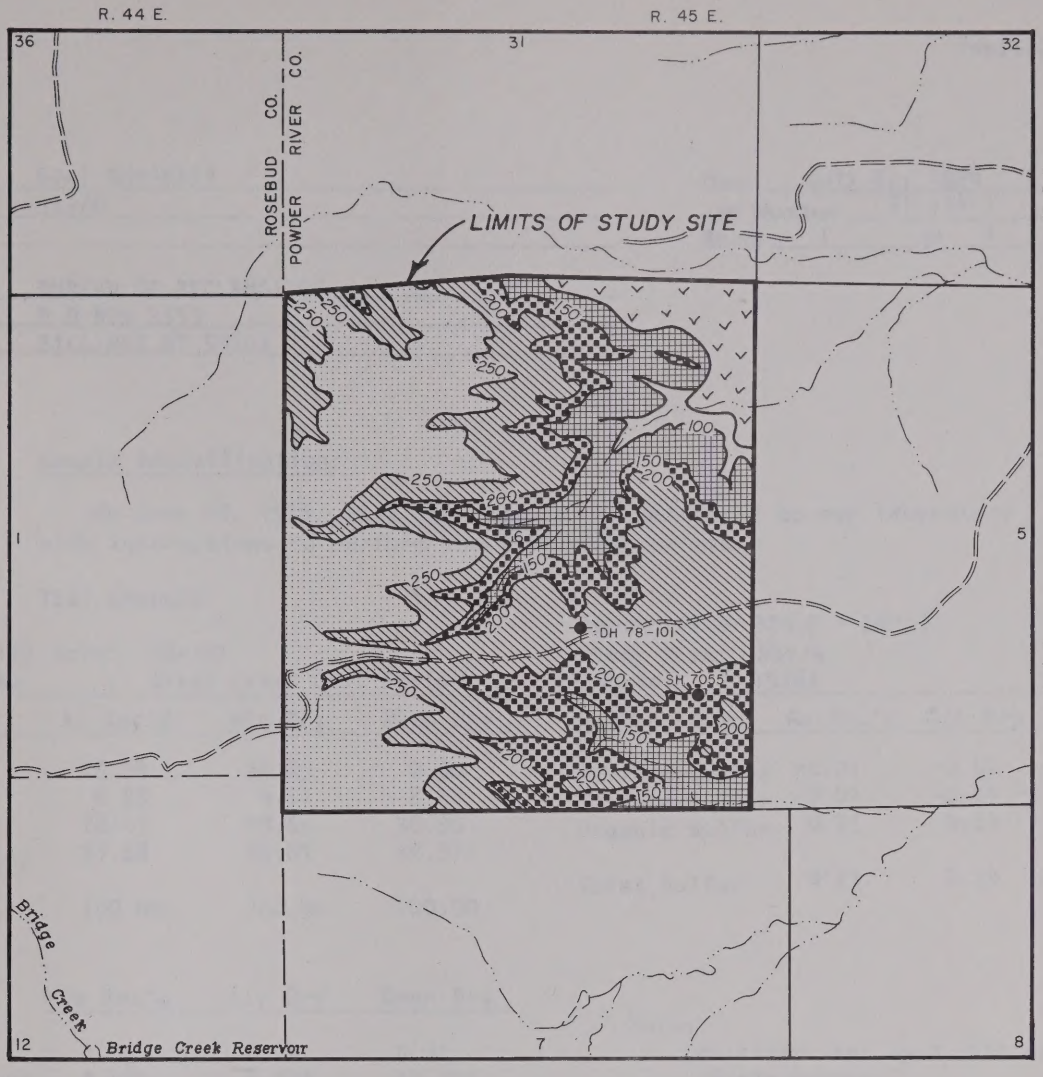
Weakly developed loamy soil profiles are most common. This material is permeable, retains up to 2 inches (51 mm) of water per foot (.3 m), is well drained and is relatively stable. Precipitation enters and moves through this soil readily, therefore surface runoff is minimal. The vertical water movement has usually leached the soluble salts below 18 inches (.45 m). Free carbonates occur just below the surface layer and the subhorizons are often saline and may be gypsiferous.

These soils are well suited for use as plant media, however, they occupy only a small total acreage in this study site.

Colluvial Soils

The colluvial soils are on footslopes and fans in the upland. They have developed under a mid and short grass plant association that has a moderate amount of big sage and forbes. Slope gradients range from 4 to 15 percent.

Loamy and fine loamy soil profiles with moderate development are most common. The physical and chemical properties of the surface few inches are similar to the alluvial soils. The lower horizons and substrata have retained many of the physical and chemical properties of the parent material. This material is usually fine textured, slowly permeable and saline. It retains about 2 inches (51 mm) of available water per foot (.3 m). Surface runoff and erosion are in part slope dependent. In these land areas it is moderate.



EXPLANATION

CLINKER – Altered shale, siltstone and sandstone of the Fort Union Formation produced by burning of the Knoblock coalbed.

OVERBURDEN ABOVE KNOBLOCK COALBED

- 50 to 100 Feet
- 100 to 150 Feet
- 150 to 200 Feet
- 200 to 250 Feet
- Over 250 Feet

—150— Contour showing depth to top of Knoblock coalbed.

DH 78-101 USBR Drill hole

SH 7055 Drill hole from USGS Miscellaneous Field Studies Map MF-802.

1000 0 1000 2000 3000

SCALE OF FEET

NOTES

An insufficient number of drill holes were located in the Study Site area to allow contouring of the top of the Knoblock coalbed. The contours showing depth to the top of the Knoblock are based on the assumption that the coalbed lies horizontally with the top at an elevation of 3034.5 feet as indicated by DH 78-101.

Thicknesses and distances measured in feet. Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

SHY/6 STUDY SITE
OTTER CREEK COALFIELD – MONTANA

OVERBURDEN THICKNESS MAP KNOBLOCK COALBED

GEOLOGY L. PARISH SUBMITTED

DRAWN L.E. ALLSOP RECOMMENDED

CHECKED APPROVED

BILLINGS, MONTANA SEPTEMBER 1978

1305-600-162

Report of: Coal Analysis
Shy/6

Date July 27, 1978
Job Number 61-114-1
Sheet 1 of 1

Report to: BUREAU OF RECLAMATION (2)
P O BOX 2553
BILLINGS MT 59103

Sample Identification:

On June 28, 1978, this coal sample was delivered to our laboratory with instructions to perform the following analyses.

TEST RESULTS:

Drill Hole: 78-101
Area : Otter Creek Coal Field

Depth, ft.: 220.5 - 287.5
Study Site: Shy/6
Lab No. : 15161

Proximate	As Rec'd	Air Dry	Oven Dry
% Moisture	28.04	23.89	0.00
% Ash	6.25	6.61	8.68
% Volatile	28.03	29.65	38.95
% Fixed Carbon	37.68	39.85	52.37
Total	100.00	100.00	100.00

Sulfur Forms	As Rec'd	Air Dry	Oven Dry
Pyritic Sulfur	-0.01	-0.01	-0.01
Sulfate Sulfur	-0.01	-0.01	-0.01
Organic Sulfur	0.23	0.24	0.32
Total Sulfur	0.23	0.24	0.32

	As Rec'd	Air Dry	Oven Dry
% Sulfur	0.23	0.24	0.32
BTU, per pound	8,485	8,975	11,792
BTU, per pound, ash, moisture free			12,913

Note:
Multiply feet by 0.3048 to obtain meters.
Multiply Btu/pound x 1.80 to obtain Kilogram-calories/kilogram.

Ultimate	As Rec'd	Air Dry	Oven Dry
% Carbon	38.38	40.59	53.33
% Hydrogen**	6.14	5.85	4.17
% Nitrogen	0.79	0.84	1.10
% Oxygen**	48.21	45.87	32.40
% Ash	6.25	6.61	8.68
% Sulfur	0.23	0.24	0.32
Total	100.00	100.00	100.00

**Includes coal moisture content in accordance with ASTM D3176.

Certified Jay C. Lyndes

RESOURCE AND POTENTIAL RECLAMATION EVALUATION
OF
SHY/6 STUDY SITE
OTTER CREEK COALFIELD
SECTION 6, T. 4 S., R. 45 E.

COAL RESERVES AND OVERBURDEN VOLUMES AND RATIOS

KNOBLOCK COALBED 1/

Thickness of Overburden Ft.	Measured and Indicated Reserves Million Tons	Overburden Million Cubic Yards	Overburden Ratio Cubic Yards Per Ton	Acres	Tons Per Acre	
50-100	1.07	1.16	1.08	9	118,888	
100-150	7.83	13.31	1.70	66	118,636	
150-200	14.11	33.60	2.38	119	118,571	
200-250	24.90	76.23	3.06	210	118,571	
250+	21.11	91.90	4.35	178	118,595	
	Total 69.02	Total 216.20	Average 3.13 2/	Total 582 3/	118,652	Average

FOOTNOTES:

1/ Knoblock coalbed is 67.0 feet thick in U. S. B. R. Drill Hole DH78-101.
2/ The average shown is a weighted average based on the number of acres per individual ratio.
3/ The Knoblock coalbed has been burned on an additional 34 acres of the section.

English to Metric Conversions

Multiply	By	To Obtain
Feet	0.3048	Meters
Acres	0.4047	Hectares
Tons	0.9072	Tonnes
Cubic Yards	0.7646	Cubic Meters

Table 3

LAND CLASSIFICATION SPECIFICATIONS - SURFACE MINE RECLAMATION
Suitability of Overburden for Revegetation of Surface-Mined Areas
BLM/BR Cooperative Program EMRIA

Shy/6 Study Site

Table 4
United States
Dept. of the Interior
Bureau of Reclamation
July 1977

Overburden Characteristics	Symbols Basic Subclass	Symbols Inform. & Defic.	Class 1	Class 2	Class 3
SOILS AND/OR BEDROCK	s				
Textures			Sandy loams to clay loams.	Sandy loam to silty clay loam.	Loamy sand to clay.
Coarse		v		Sandy loams sufficiently coarse to slightly reduce productivity, moisture retention and may increase erosiveness slightly.	Loamy sand in sufficient quantity to moderately reduce productivity and moisture retention, and may increase erosiveness moderately.
Fine		h		Profile should have sufficient material for top dressing; clayey type materials that are moderately permeable should be placed below .15 m in the reconstructed profile.	Profile should have sufficent material for top dressing; placement of clay in reconstructed profile; permeable .25 m plus; slowly permeable .75 m plus.
Depth		d	1 m of overburden that is suitable for plant media.	.5 m of overburden that is suitable for plant media.	.25 m of overburden that is suitable for plant media.
Sodicity		a	SAR not to exceed 9.0 in clay textured material but may be 20.0 in loam sand. Values may be higher if compensated by adequate gypsum.		
Salinity (m^s/cm)		s	Overburden with characteristics (chemical and physical) capable of producing an expected electrical conductivity at equilibrium with the natural precipitation must be readily available as follows:		
			Less than 4 m^s/cm	Less than 8 m^s/cm except the surface .25 m must be 4 m^s/cm	Less than 12 except the surface .25 m must be 4 m^s/cm
Available Water Holding Capacity		q	38 mm/.3m foot of overburden	.25 mm/.3m of overburden	.19 mm/.3m of overburden
Hydraulic Conductivity		p	Adequate to provide a well drained and aerated root zone and an infiltration rate adequate to prevent serious erosion.	Slightly restricted; movement of drainage water and aeration in the lower root zone will be reduced. Infiltration rate may be reduced and erosion hazard increase slightly.	Restricted in the lower root zone and internal drainage may limit choice of plant species. Restricted infilitration may create serious but controllable erosion hazard.
Indurated Sandstone Stones and cobble		x	Permissible stone in overburden that may be stockpiled and reused as surface soil 0 to .25 m 5%.	Permissible stone in overburden that may be stockpiled and reused as surface soil 0 to .25 m 10%.	Permissible stone in overburden that may be stockpiled and reused as surface soil 0 to .25 m 20%.
Weatherability 1/			Will break down readily upon exposure to the weather.	May require short period to break down upon exposure.	May require extended period to break down.
Erodibility		e	Slight.	Moderate, controllable with average management.	Severe but controllable with above average management and selective placement of overburden.
TOPOGRAPHY 2/	t				
Slope		g	Permissible surface gradient g - 0 to 12% with smooth slopes.	Permissible surface gradient g - 0 - 20%.	Permissible surface gradient g - 0 - 35%.
Indurated Sandstone Massive and lenticular		r	None.	1 to 5% of area.	5 to 20% of area.
Cover		c	Not applicable.		
DRAINAGE	d		(Present drainage conditions, surface and subsurface) are not a factor in this classification because of the anticipated land disturbance during mining. All soil properties evaluated to classify the land were also considered in evaluating material that may be placed in the subsurface drainage zone, but this evaluation did not affect the land classes.		
Class 6			Areas delineated in this class generally lack suitable material for stripping and stockpiling for surface use. One or a combination of the following deficiencies may result in the use of this class: (1) insufficient surface soil and bedrock of suitable quality at or near the surface; (2) topography which prevents general stripping and stockpiling; (3) rocklands with large amounts of massive indurated sandstone; (4) toxic overburden (soil and bedrock) on or near the surface. Reclamation of these lands will require material from outside the delineated area, from deep geologic strata, or special treatment of available material.		

1/ Applicable only to unweathered bedrock material.
2/ Not applicable to unweathered bedrock material.

The upper 12 (.3) to 18 inches (.45 m) of soil are well suited for plant media. This material may be placed at or near the surface of reconstructed profiles. Lower horizons are best suited for use below the surface layer.

Residual Soils

In this site the shallow residual soils have the largest areal distribution and are on narrow ridges, knobs and steep eroded slopes. The vegetative cover is variable and reflects the interaction of slowly permeable soils, slope gradient and the resultant erosion. Mid and short grasses are most common, but the number of forbes and salt tolerant sedges and shrubs is high. Slope gradients range from 4 to over 35 percent. The rate of erosion is usually high.

Soil profile development is minimal and the physical and chemical properties below the surface 2 (51) to 5 inches (127 mm) are similar to the underlying Fort Union Formation. This subsurface material is fine textured, slowly permeable, commonly saline and sodic, silty to clayey shale.

A composite of the surface 6 inches (152 mm), the approximate minimum stripping depth, will be fair-to-good for use as plant media. Raw shale exposures and rock outcrops are included in this soil type.

Description of Classes

Class 1 land has no major soil an/or topographic limitations. Topographically, this land is well suited for stripping and stockpiling good quality overburden for use as plant media. The physical and chemical properties of this material make it suitable for use at or near the surface of reconstructed profiles. Land in this class is usually a good source of topdressing material. Excess material may be used in tracts with insufficient good quality plant media.

Class 2 land has few soil and topographic limitations. Topographically this land can be stripped and stockpiled without special practices. The suitability of this material for use as plant media is reduced because of texture, permeability, salinity or quantity. Class 2 land has sufficient material for reclamation, but is only a fair-to-poor source of borrow material.

Class 3 land is limited by topography and soils. Special measures such as selective stripping and borrowing topdressing material for localized tracts will be required. Most Class 3 land will have sufficient suitable overburden for reclamation. However, the reclamation potential will be lower because of quantity, texture, permeability, salinity or sodicity. A high level of management will be required for optimum reclamation through revegetation.

Class 6 land does not have sufficient suitable overburden for reclamation. Material must be borrowed or the available material modified for optimum results. The topography and land conditions also limit stripping.

Steep eroded slopes, bluff-forming sandstone and rock outcrops are common. However, selective stripping of the best material will reduce the amount of borrow required.

Methods and Procedures

The chemical and physical properties of soil profiles were evaluated in typical land areas and the land classes were delineated on photographs. Most profiles were sampled for testing in the soil laboratory. After the laboratory tests were completed, the land classes were finalized on reproducible drawings.

Standard laboratory procedures for pH, conductivity (salts), water movement, and soil stability were performed on all samples. Trace elements and heavy metals were determined on the bedrock cores.

Typical profile descriptions are recorded on Tables 6 and 8. Erosion conditions are shown on Tables 5 and 7. Tables 5 through 8 are in the Appendix.

Results of Classification

Class 1 land occurs on 7 percent of the study site. This material is usually loamy textured, of good quality and will be easily stripped and stockpiled.

Class 2 land makes up only 15 percent of this site. The major soil deficiencies are salinity and permeability. Sodium and rock are the other deficiencies.

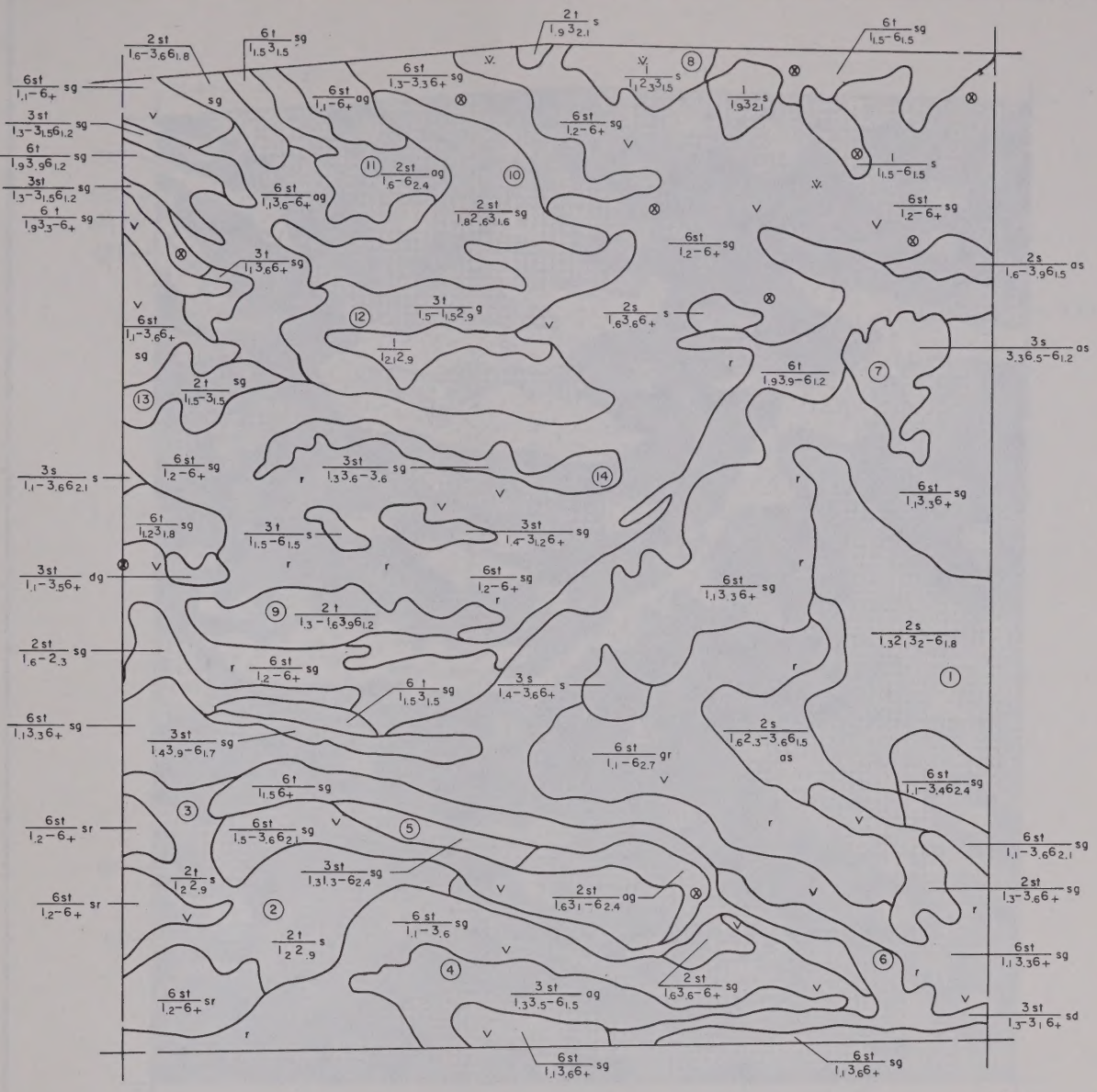
Class 3 land occurs on 12 percent of the area. Soil deficiencies are sodicity, salinity and permeability. Some slick spots and rock and shale outcrops are included in this class. Some borrow will be required, but resurfacing material is adequate in most tracts.

Class 6 land represents 66 percent of the site. Small inclusions of good soil occur, but it is doubtful if they merit selective stripping.

The location and areal distribution of the land classes are shown on Plate 5. This drawing also shows the soil and topographic deficiencies.

Results of the screenable tests in the soil laboratory are recorded on Table 9 in the Appendix.

Plate 6 shows the location and the approximate depth of the topsoiling material and Plate 7 shows location, depth and soil deficiencies of subsoil material.



SOIL PROFILE NOTES

PROFILE REPRESENTS 1.5 METERS DEPTH

(3) SOIL PROFILE NUMBER

C.L.	2.8 / 8.4-8.0	2.8 EC mmhos cm. Sat. Ext. 8.4 pH 1:5 Soil Water Suspension 8.0 pH Soil - $CaCl_2$ Suspension
.65 / .24 Lt.C.		.65 Hydraulic Conductivity - in./hr. (Disturbed Sample) .24 Settling Volume
Gr.		

SOIL PROFILE SYMBOLS

Cb	Cobble
Gr	Gravel
S	Sand
LS	Loamy Sand
SL	Sandy Loam
L	Loam
SiL	Silt Loam
SCL	Sandy Clay Loam
CL	Clay Loam
SiCL	Silty Clay Loam
SC	Sandy Clay
C	Clay
SiC	Silty Clay
Sh	Shale
Ss	Sandstone
F	Fine
Lt	Light
M	Medium
H	Heavy

INFORMATIVE SYMBOLS

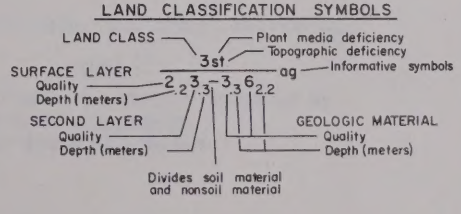
OVERBURDEN DEFICIENCIES (for plant media)

- a Salinity
- s Sodicity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- x Stoniness

TOPOGRAPHIC DEFICIENCIES

- g Slope (including gradient and complexity)
- r Massive lenticular sandstone and or Glacial erratics
- c Cover

LAND CLASSIFICATION SYMBOLS



CONVENTIONAL AND SPECIAL MAP SYMBOLS

LAND FEATURES

- Blowout
- Clay spot
- Gravelly spot
- Gumbo, slick or scaby spot (sodic)
- Dumps and similar nonsoil areas
- Rock outcrop (includes shale and sandstone)
- Baked rock - clinker (local name scoria)
- Slide or slip (tips point upslope)
- Stony spot, very stony spot
- Greasewood
- Soil profile (check)

WATER FEATURES

- Marsh or swamp
- Spring
- Well, artesian
- Well, irrigation
- Wet spot

PITS

- Gravel
- Mine

DAMS

- Medium or small

Section 6, T. 4 S. - R. 45 E.

250 0 250 500

SCALE OF METERS

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

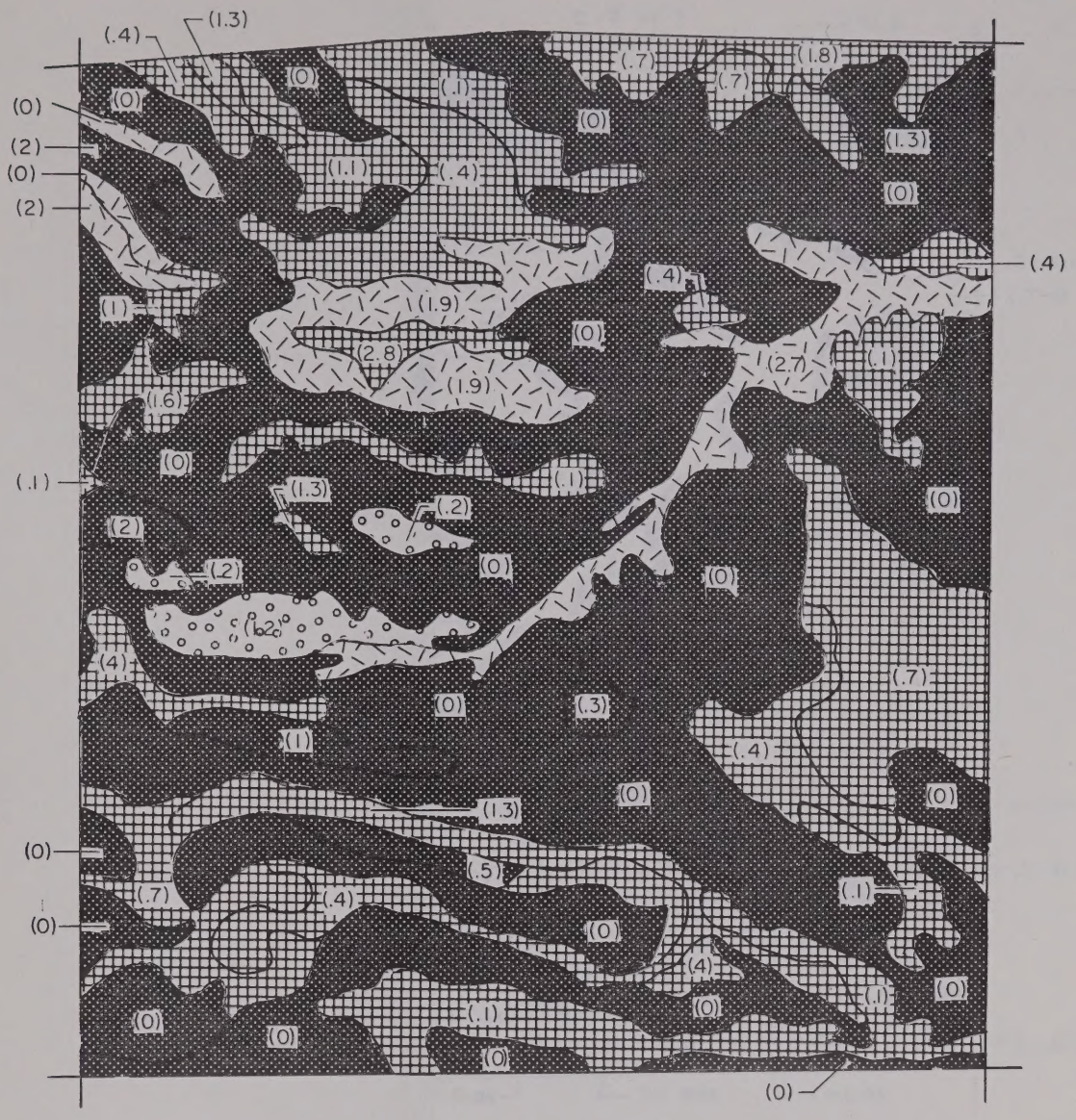
RESOURCE & POTENTIAL RECLAMATION EVALUATION

SHY/6 SITE
OTTER CREEK COALFIELD - MONTANA

SEMI-DETAILED LAND CLASSIFICATION

LANDS H.B. WARD	SUBMITTED
DRAWN L.E. ALLSOP	RECOMMENDED
CHECKED	APPROVED

BILLINGS, MONTANA MARCH 1978 1305-600-163



EXPLANATION

DEPTH OF TOPSOILING MATERIAL

MATERIAL FOR USE ON OR NEAR THE SURFACE

	METERS	ACRES
	0 – 0.1	360.7
	0.1 – 0.2	214.7
	0.2 – 0.3	12.9
	0.3 – 1.0	27.7

TOTAL ADDITIONAL SUITABLE MATERIAL

(1.6) 1/

1/ Material over the amount indicated by the zip-a-tone symbols. Best use below 0.1 meters

Section 6, T. 4 S. – R. 45 E.

250 0 250 500 750

SCALE OF METERS

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

SHY/6 SITE

OTTER CREEK COAL FIELD-MONTANA

TOPSOILING MATERIAL

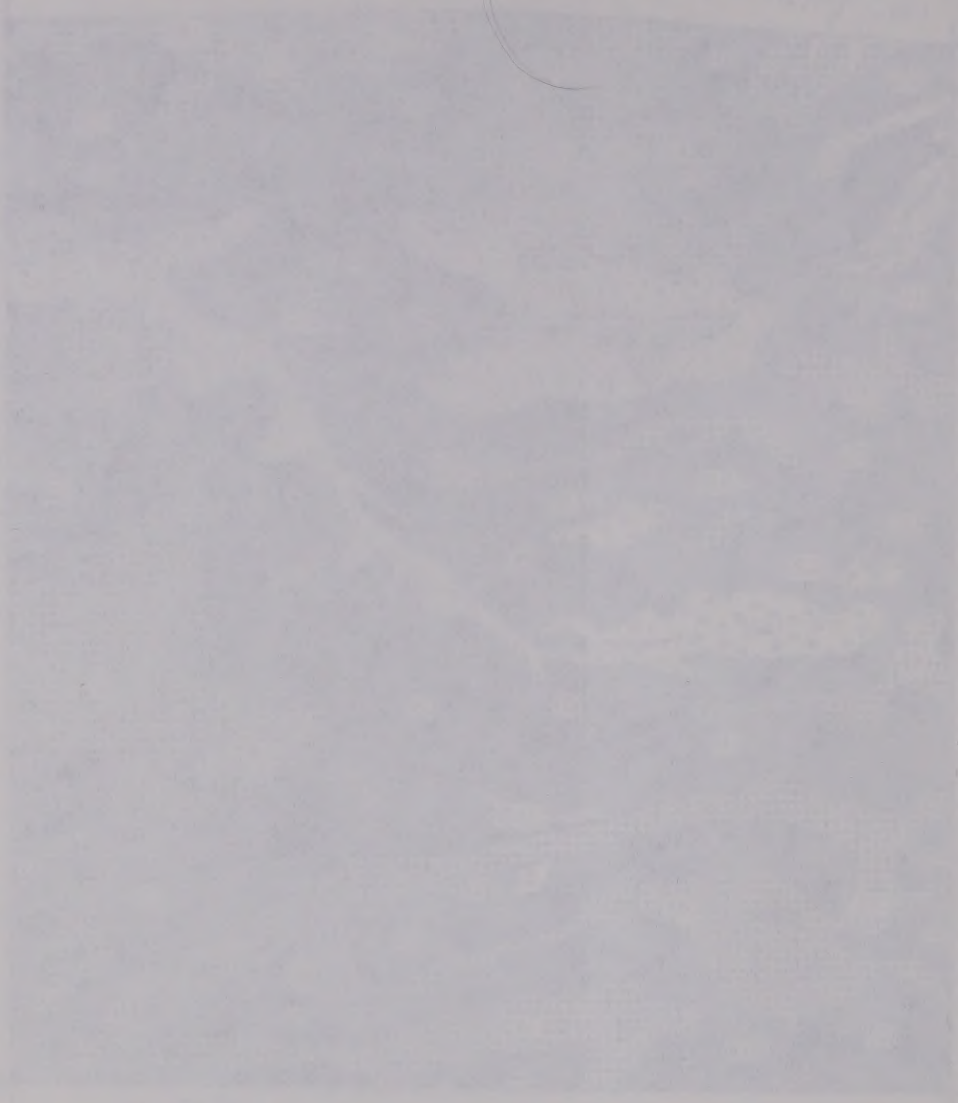
LANDS H.B. WARD SUBMITTED

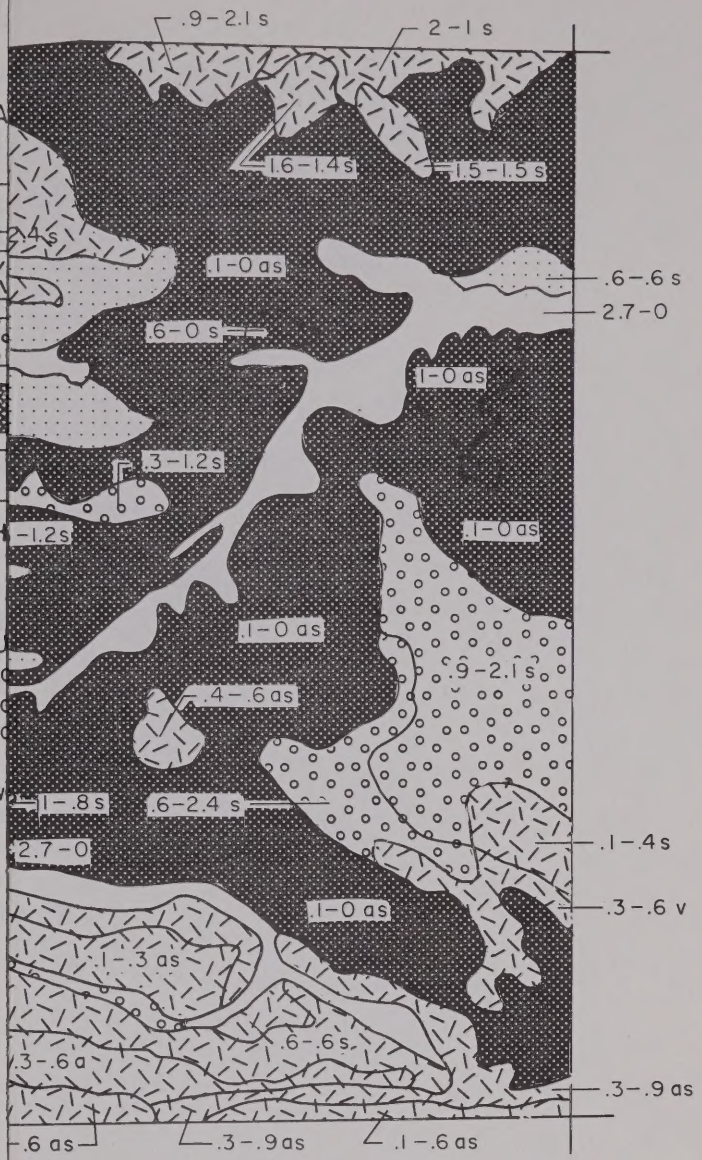
DRAWN L.E. ALLSOP RECOMMENDED

CHECKED APPROVED

BILLINGS, MONTANA APRIL, 1978

1305 - 600 - 164





Section 6, T. 4 S. - R. 45 E.

250 0 250 500 750

SCALE OF METERS

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

SHY/6 SITE
OTTER CREEK COAL FIELD-MONTANA
SUBSURFACE MATERIAL

LANDS H B WARD	SUBMITTED
DRAWN L E ALLSOP	RECOMMENDED
CHECKED	APPROVED

BILLINGS, MONTANA APRIL 1978 | 1305-600-165

EXPLANATION

MATERIAL SUITABLE FOR SUBSURFACE PLACEMENT

QUALITY OF MATERIAL

- Good
- Fair
- Poor
- NS (Not Suitable)
- Material to 3 meters is suitable for use at or near the surface.

DEPTH TO MATERIAL FOR SUBSURFACE PLACEMENT 6' 1/

NOTE

Usable material for subsurface, as used in this report includes that portion of the overburden (soil mantle and bedrock) that should be placed 1/ below the primary plant root zone in reconstructed profiles. It contains no known toxic elements but may be clayey, sandy or highly saline. However, the soluble salts will leach from material subjected to downward movement of natural precipitation.

1/ Unless modified by leaching, mixing or other measures.

INFORMATIVE SYMBOLS

OVERBURDEN DEFICIENCIES
(for plant media)

- a Salinity
- s Sodicity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- x Stoniness

TOPOGRAPHIC DEFICIENCIES

- g Slope (including gradient and complexity)
- r Massive lenticular sandstone and/or Glacial erratics.
- c Cover

Section 6, T. 4 S. - R. 45 E.

250 0 250 500 750

SCALE OF METERS

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

SHY/6 SITE
OTTER CREEK COAL FIELD - MONTANA
SUBSURFACE MATERIAL

LANDS H.B. WARD	SUBMITTED
DRAWN L.E. ALLSOP	RECOMMENDED
CHECKED	APPROVED

BILLINGS, MONTANA APRIL, 1978 | 1305-600-165

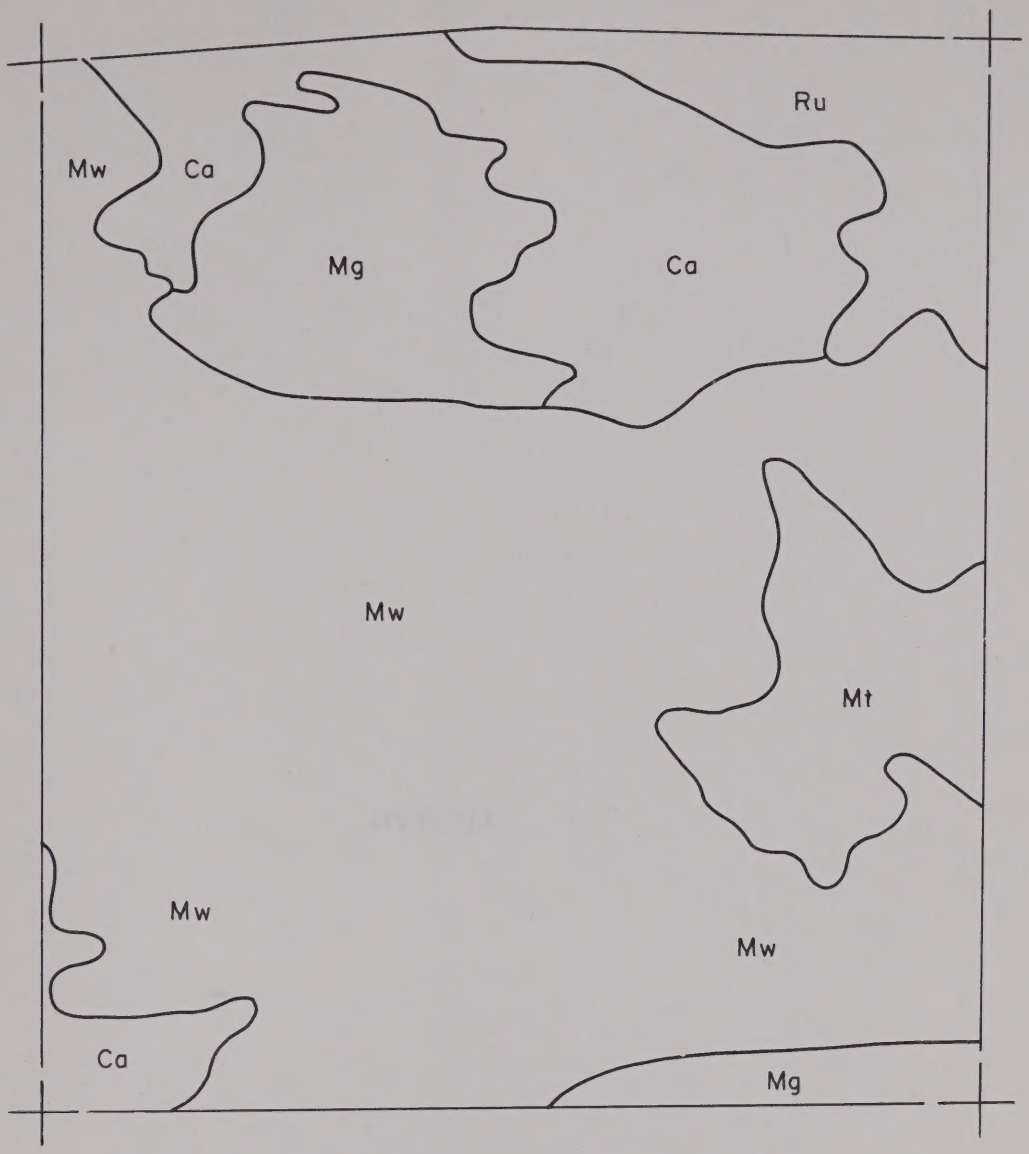
Soil Inventory

The Powder River Area soil survey data are shown on Plate 8.

Reclamation Potential

The soil conditions in this site are minimal for reclaiming if the site is surface mined. The soil and topographic conditions are only suited for returning the site to range vegetation. The amount of good and high quality material that is suitable for plant media is very limited. Adding borrow material to class 6s and 6st tracts is necessary for satisfactory reclamation with range vegetation. After revegetation minimal stocking rates are necessary to assure permanent establishment of vegetation. To achieve optimum productivity levels under post-mining conditions, all material in excess of minimum needs for revegetating the site with range plants should be stockpiled from Classes 1, 2 and 3 for use in Class 6 areas. The quantity and quality of this material would be determined by the salinity, sodicity, permeability, and clay content of the upper part of the weathered bedrock. Mixing and material modification may be required. Another measure that should be considered and used where applicable, is the reduction of slopes, especially those that are moderately steep and face to the south or southwest.

The mining plan should also provide for the use of current approved land preparation and planting methods. Plant species, that are compatible with the minimal quality and quantity of plant media should be selected. Salt tolerant plants and those that produce with shallow root systems should be in the seeding mixture.



	SOIL SERIES	SLOPE - %
Ca	Cabba association	15 - 50
Mg	Midway-Elso association	8 - 35
Mt	Midway-Thurlow association	8 - 15
Mw	Midway and Elso rocky soils	35 - 75
Ru	Ringling-Relan association	6 - 25

Section 6, T. 4 S. - R. 45 E.

250 0 250 500 750

SCALE OF METERS

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION
SHY/6 SITE
OTTER CREEK COAL FIELD-MONTANA
SOIL SURVEY MAP

LANDS H B WARD SUBMITTED
DRAWN L E ALLSOP RECOMMENDED
CHECKED APPROVED

BILLINGS, MONTANA APRIL, 1978 1305-600-166

APPENDIX

Form 7310–12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

By | Date 11/78

Location (F) Sect. 6 .. T 4 S .. R 45 E

Treatment affecting the SSF

DETERMINATION OF EROSION CONDITION CLASS

SOIL SURFACE FACTORS (SSF)

SOIL MOVEMENT*	No visual evidence of movement 0 1 2 3	Some movement of soil particles 4 5	Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height. 6 7 8	Occurs with each event. Soil and debris deposited against minor obstructions. 9 10 11	Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions 12 13 (14)
SURFACE LITTER*	Accumulating in place 0 1 2 3	May show slight movement 4 5 6	Moderate movement is apparent, deposited against obstacles 7 8	Extreme movement apparent, large and numerous deposits against obstacles 9 10 11	Very little remaining *(use care on low productive sites)* (12) 13 14
SURFACE ROCK*	If present, the distribution of fragments show no movement caused by wind or water 0 1 2	If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water 3 4 5	If present, fragments have a poorly developed distribution pattern caused by wind or water 6 7 8	If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles (9) 10 11	If present, surface rock or fragments are dissected by rills and gullies or are already washed away 12 13 14
PEDESTALLING*	No visual evidence of pedestalling 0 1 2 3	Slight pedestalling, in flow patterns 4 5 6	Small rock and plant pedestals occurring in flow patterns 7 8 (9)	Rocks and plants on pedestals generally evident, plant roots exposed 10 11	Most rocks and plants pedestalled and roots exposed 12 13 14
FLOW PATTERNS*	No visual evidence of flow patterns 0 1 2 3	Deposition of particles may be in evidence 4 5 6	Well defined, small, and few with intermittent deposits 7 8 (9)	Flow patterns contain silt and sand deposits and alluvial fans 10 11 12	Flow patterns are numerous and readily noticeable. May have large barren fan deposits. 13 14 15
RILLS	No visual evidence of rills 0 1 2 3	Some rills in evidence at infrequent intervals over 10' 4 5 6	Rills ½" to 6" deep occur in exposed places at approximately 10' intervals 7 8 9	Rills ½" to 6" deep occur in exposed area at intervals of 5 to 10' 10 11 12	May be present at 3" to 6" deep at intervals less than 5' 13 (14) →
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes 0 1 2 3	A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes. 4 5 6	Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present. (7) 8 9	Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length 10 11 12	Sharply incised gullies cover most of the area and over 50% are actively eroding 13 14 15

SITUATION	TOTAL				
			(74)		

Erosion Condition Classes: Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100

(Instructions on reverse)

Table 5

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State	2. District	3. Planning Unit	4. Vegetation–Soil Unit	5. Soil Map Symbol	6. Surname	7. Date
Mont	02	08	———— / ————	————	Fiechtl	11 mo 78 yr

8. Area	9. County	10. Location	11. Photo No.	12. Writeup No.	13. File No.	14. Parent Rock
78	P. River	Sec. 4, T. 4S, R. 45E	————	————	————	Sandstone

15. Formation Name	16. Surface Conditions (percent)	17. Land Conditions	18. Landform
Fort Union	Stone — Rock —	Alkaline Mod Saline Mod. Water table —	Residual

19. Slope (percent)	20. Aspect	21. Elevation	22. Present Erosion	23. Hydrologic Group
8-35%+ ☐ Single ☑ Complex	E	936 m	Severe Type Gully SSF 45 Class Critical	B

24. Precipitation (in)	25. Temperature	26. Frost-free	27. Drainage Class	28. Infiltration	29. Percolation	30. ERD	31. AWC
.3-4m 1st , 2nd , 3rd , 4th	— Air — Soil	Days 100 -> 28°	Excessive	Slow	Slow	.41 m/m	.05 m per .3 m

32. HORIZON	33. THICKNESS m	34. COLOR DRY MOIST — MATRIX	34. COLOR DRY MOIST — MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
A1	0-.05	(D) 2.5YR 5/2 (M) " 3/2		L	m 2 gr/ f 2 gr	(D) So (M) vfr	—	2 f	—	e	g
AC	.05-.20	(D) 2.5YR 4/2 (M) " 5/2		gr L	m 1 bk/ f 1 bk	(D) So (M) vfr	—	2 f	Slw 4	es	g
C1	.20-.45	(D) 2.5YR 4/3 (M) " 5/2		—	—	—	—	1 f	"	es	g
C2	.45+	(D) 2.5YR 4/3 (M) " 5/2		—	—	—	—	—	"	—	

Area predominately has less than .15 m of usable surface materials due to loss of surface materials. .05-.20 is a slatty loam over weathered baked reddish-brown shales. Fractured baked shales at .45 m +.

(F) 700'S., 350'W of NE Cor.

(Instructions inside back cover)

Form 7310–9a (December 1970)

Table 6

Form 7310–12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

By | Date 11/78

Location (E) Center Sect. 6., T. 4 S., R. 45 E.

Treatment affecting the SSF

DETERMINATION OF EROSION CONDITION CLASS
SOIL SURFACE FACTORS (SSF)

SOIL MOVEMENT *	No visual evidence of movement 0 1 2 3	Some movement of soil particles 4 5	Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height. 6 7 8	Occurs with each event. Soil and debris deposited against minor obstructions. 9 10 11	Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions 12 13 (14)
SURFACE LITTER *	Accumulating in place 0 1 2 3	May show slight movement 4 5 6	Moderate movement is apparent, deposited against obstacles 7 8	Extreme movement apparent, large and numerous deposits against obstacles 9 10 11	Very little remaining *(use care on low productive sites)* 12 13 (14)
SURFACE ROCK *	If present, the distribution of fragments show no movement caused by wind or water 0 1 2	If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water 3 4 5	If present, fragments have a poorly developed distribution pattern caused by wind or water 6 7 8	If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles 9 10 11	If present, surface rock or fragments are dissected by rills and gullies or are already washed away (12) 13 14
PEDESTALLING *	No visual evidence of pedestalling 0 1 2 3	Slight pedestalling, in flow patterns 4 5 6	Small rock and plant pedestals occurring in flow patterns 7 8 9	Rocks and plants on pedestals generally evident, plant roots exposed 10 11	Most rocks and plants pedestalled and roots exposed 12 13 (14)
FLOW PATTERNS *	No visual evidence of flow patterns 0 1 2 3	Deposition of particles may be in evidence 4 5 6	Well defined, small, and few with intermittent deposits 7 8 9	Flow patterns contain silt and sand deposits and alluvial fans 10 11 (12)	Flow patterns are numerous and readily noticeable. May have large barren fan deposits. 13 14 15
RILLS	No visual evidence of rills 0 1 2 3	Some rills in evidence at infrequent intervals over 10' 4 5 6	Rills ½" to 6" deep occur in exposed places at approximately 10' intervals 7 8 9	Rills ½" to 6" deep occur in exposed area at intervals of 5 to 10' 10 11 12	May be present at 3" to 6" deep at intervals less than 5' 13 (14)
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes 0 1 2 3	A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes. 4 5 6	Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present. 7 8 9	Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length 10 11 (12)	Sharply incised gullies cover most of the area and over 50% are actively eroding 13 14 15
SITUATION	TOTAL				
			(92)		

Erosion Condition Classes: Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100

(Instructions on reverse)

Table 7

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State	2. District	3. Planning Unit	4. Vegetation–Soil Unit	5. Soil Map Symbol	6. Surname	7. Date
Mont	02	08	———— / ————	————	Fischl	— mo 78 yr

8. Area	9. County	10. Location	11. Photo No.	12. Writeup No.	13. File No.	14. Parent Rock
78	P. River	Sec. 6, T. 4 S, R. 45 E.	————	————	————	Sandstone

15. Formation Name	16. Surface Conditions (percent)	17. Land Conditions	18. Landform
Fort Union	Stone — Rock —	Alkaline — Saline — Water table None	Residual

19. Slope (percent)	20. Aspect	21. Elevation	22. Present Erosion	23. Hydrologic Group
8-35%+ ☐ Single ☑ Complex	E	960m	Severe Type Deep & Shallow Gullies SSF 92 – Class Severe	D

24. Precipitation (in)	25. Temperature	26. Frost-free	27. Drainage Class	28. Infiltration	29. Percolation	30. ERD	31. AWC
12-16" 1st , 2nd , 3rd , 4th	— Air — Soil	Days 100 > 28°	Excessive	Slow	Slow	.36 m/m	.05 m per m .3

32. HORIZON	33. THICKNESS m	34. COLOR DRY MOIST — MATRIX	34. COLOR DRY MOIST — MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
A1	0-.05	(D) 10YR 6/4 (M) " 5/4		<Cl	m2pl/ m2gr	(D) so (M) vfr	—	2f	—	es	g
AC	.05-.22	(D) 2.5Y 6/4 (M) " 5/4		Cl	massive	(D) sh (M) fr	—	2f	—	ev	a
C1	.22-.43	(D) 2.5Y 7/3 (M) " 6/3		CL	"	(D) h (M) fi	—	1f	—	ev	a
C2	.43-	(D) 2.5Y 7/2 (M) " 6/3		CL>	"	(D) h (M) fi	—	1f	—	ev	

Stratified silty, sandy, clayey, carbonacious materials occur below the surface materials. Segregated lime and gypsum occur throughout profile. Steep side slopes expose shale and sandstone outcrops above deep narrow colluvial gullies. Coal like seams may occur throughout the area. Shallow and moderately deep soils may occur on narrow ridges, bench remnants, tabular divides.

Table 8

(Instructions inside back cover)

(E) Center section 6-4-45

Form 7310–9a (December 1970)

UNITED STATES - DEPARTMENT OF THE INTERIOR - BUREAU OF RECLAMATION - UPPER MISSOURI REGION

SOIL LABORATORY - MILES CITY, MONTANA

UNIT SHY/6 PROJECT

SOIL SCIENTIST [illegible] LOCATION - SECTION 6 T. 45 R. 45E DATE 11/77

LAB NO.	PROFILE NO.	DEPTH METERS	TEXTURE		pH		SET. VOL. ml	EC		FRAG. HYD. COND.		SODIUM ABSORPTION RATIO			GYP. REQ. me/100g	PARTICLE SIZE PERCENTAGE			HCL	%
			FIELD	LAB	1-5	$CaCl_2$		1-5	SAT. EXT.	8 hr. in./hr.	24 hr. in./hr.	TSC me/l	Cat.Mg. me/l	SAR		SAND	SILT	CLAY		
1	162	0-.30	>CL	S/CL	8.3		23	0.90 0.12		2.88	+ 8.00					26	34	40	+	
	163	.30-.76	CL		8.5		25	7.60 1.15	7.0	0.36	0.64								H	
	164	.76-1.2	CL		8.7	8.5	23	15.00 3.20	20.0	0.84	0.52 ~~5.20~~								++	
	165	1.2-1.8	CL		8.2		32	18.00 4.70	31.0	0.29	0.54								++	
	166	1.8-2.4	CL		8.4		28	8.00 1.30	7.5	0.27	0.40								++	
	167	2.4-3.0	CL		8.7	7.8	23	2.80 0.34		0.28	0.33								+/	
2	168	0-.46	>SiL		8.1		23	1.00 0.13		2.32	7.24								+	
	169	.46-.91	< CL		8.3		23	1.00 0.13		0.62	2.08								+	
	170	.91-1.4	CL		8.0		22	3.00 0.38		0.46	0.70								+	
	171	1.4-2.0	CL		8.1		22	3.40 0.44		0.38	0.56								+-	
	172	2.0-2.4	CL		8.3		20	2.20 0.28		0.60	1.40								++	
	173	2.4-3.0	CL		8.4		21	2.60 0.32		0.62	1.24								++	

DOUBLE LINES INDICATE SOIL-BEDROCK CONTACT

Table 9 sheet 1 of 8

UNITED STATES - DEPARTMENT OF THE INTERIOR - BUREAU OF RECLAMATION - UPPER MISSOURI REGION

SOIL LABORATORY - MILES CITY, MONTANA

UNIT SHV/6 PROJECT

SOIL SCIENTIST LOCATION - SECTION 6 T. 45 R. 45E DATE 11/77

LAB NO.	PROFILE NO.	DEPTH METERS	TEXTURE FIELD	TEXTURE LAB	pH 1-5	pH $CaCl_2$	SET. VOL. ml	EC 1-5	EC SAT. EXT.	FRAG. HYD. COND. 8 hr. in./hr.	FRAG. HYD. COND. 24 hr. in./hr.	SODIUM ABSORPTION RATIO TSC me/l	SODIUM ABSORPTION RATIO Cat.Mg. me/l	SODIUM ABSORPTION RATIO SAR	GYP. REQ. me/100g	PARTICLE SIZE PERCENTAGE SAND	PARTICLE SIZE PERCENTAGE SILT	PARTICLE SIZE PERCENTAGE CLAY	HCL	%
3	174	0-.30	CL		8.2		22	0.90 0.12		1.72	4.68								+	
	175	.30-.76	CL		8.3		22	1.00 0.13		0.54	0.80								++	
	176	.76-1.4	CL		8.3		20	1.80 0.22		0.54	1.12								++	
	177	1.4-2.0	L		8.1		20	5.00 0.67	5.0	1.20	2.80								++	
	178	2.0-2.4	L		7.9		20	5.60 0.77	5.5	0.92	2.24								++	
	179	2.4-3.0	FSL		8.0		20	4.40 0.57	6.0	1.84	4.96								++	
4	180	0-.46	<SiL		7.9		25	3.60 0.48		8.00+	8.00+								+	
	181	.46-.76	CL		8.1		25	7.00 1.00	8.0	0.10	0.09								++	
	182	.76-1.2	>CL		7.6		25	14.00 2.80	14.0	0.06	0.09								++	
	183	1.2-1.8	CL		7.7		25	17.00 3.60	15.0	0.07	0.09								++	
	184	1.8-2.3	CL		8.2		30	12.00 2.20	15.0	0.34	0.64								++	
	185	2.3-3.0	SCL		8.7	7.4	120	6.20 0.87	6.0	0.00	TR								++	

Table 9 sheet 2 of 8

UNITED STATES - DEPARTMENT OF THE INTERIOR - BUREAU OF RECLAMATION - UPPER MISSOURI REGION

SOIL LABORATORY - MILES CITY, MONTANA

UNIT SHY/6 PROJECT

SOIL SCIENTIST [illegible] LOCATION - SECTION 6 T. 4S R. 45E DATE 11/77

LAB NO.	PROFILE NO.	DEPTH METERS	TEXTURE		pH		SET. VOL. ml	EC		FRAG. HYD. COND.		SODIUM ABSORPTION RATIO			GYP. REQ. me/100g	PARTICLE SIZE PERCENTAGE			HCL	%
			FIELD	LAB	1-5	$CaCl_2$		1-5	SAT. EXT.	8 hr. in./hr.	24 hr. in./hr.	TSC me/l	Cat.Mg. me/l	SAR		SAND	SILT	CLAY		
5	186	0-.30	<CL		7.9		23	3.40 0.44		1.36	+ 8.00								+	
	187	.30-.61	CL		8.0		24	5.80 0.80	6.5	0.88	4.60								H	
	188	.61-1.2	CL		8.3		24	14.00 2.80	18.0	0.20	0.21								H	
	189	1.2-1.8	CL		8.2		31	16.50 3.80	21.0	0.20	0.10								H	
	190	1.8-2.4	>CL		8.2		27	15.00 3.20	20.0	0.15	0.18								H	
	191	2.4-3.0	SCL		8.2		27	14.00 2.80	20.0	0.07	0.08								H	
6	192	0-.30	CL	CL	7.9		22	4.20 0.55	3.7	+ 8.00	+ 8.00					38	28	34	H	
	193	.30-.61	CL/C		7.1		25	18.00 4.70	10.2	0.02	0.02								H	
	194	.61-.91	CL		7.2		29	17.50 4.50	14.1	0.00	0.02								-	
	195	.91-1.4	CL		7.4		27	18.00 4.70	12.0	0.09	0.08								H	

UNITED STATES - DEPARTMENT OF THE INTERIOR - BUREAU OF RECLAMATION - UPPER MISSOURI REGION

SOIL LABORATORY - MILES CITY, MONTANA

UNIT SHY/6 PROJECT

SOIL SCIENTIST LOCATION - SECTION 6 T. 4 R. 45 DATE 11/27

LAB NO.	PROFILE NO.	DEPTH METERS	TEXTURE FIELD	TEXTURE LAB	pH 1-5	pH $CaCl_2$	SET. VOL. ml	EC 1-5	EC SAT. EXT.	FRAG. HYD. COND. 8 hr. in./hr.	FRAG. HYD. COND. 24 hr. in./hr.	SODIUM ABSORPTION RATIO TSC me/l	SODIUM ABSORPTION RATIO Cat.Mg. me/l	SODIUM ABSORPTION RATIO SAR	GYP. REQ. me/100g	PARTICLE SIZE PERCENTAGE SAND	PARTICLE SIZE PERCENTAGE SILT	PARTICLE SIZE PERCENTAGE CLAY	HCL	%
7	196	0-.30	<CL		7.6		23	8.40 1.35	9.0	0.40	0.34								tt	
	197	.30-.76	L		9.2	8.1	36	8.00 1.30	10.0	0.00	0.00	100.0	21.5	23.4	+.4				tt	
	198	.76-1.4	<CL		8.5		33	12.00 2.20	16.0	0.04	0.03								t	
	199	1.4-2.0	<CL		8.8	7.9	33	9.20 1.60	14.0	0.02	0.01								t	
	200	2.0-2.4	<CL		8.8	8.0	36	10.00 1.80	14.0	0.00	0.00								tt	
	201	2.4-3.0	<CL		8.9	7.9	36	9.00 1.50	14.0	0.00	0.00								tt	
8	202	0-.30	CL		7.0		23	6.00 0.85	5.0	1.28	1.52								t	
	203	.30-1.1	CL		7.9		21	4.60 0.62	4.0	0.22	0.19								tt	
	204	1.1-1.5	CL		8.1		20	6.00 0.85	7.5	0.38	0.25								tt	
	205	1.5-2.1	CL		7.8		21	7.40 1.15	10.0	0.22	0.19								tt	
	206	2.1-2.6	CL		7.3		19	14.00 2.80	16.0	0.42	0.38								tt	
	207	2.6-3.0	CL		7.3		20	14.40 3.00	17.0	0.25	0.27								tt	

Table 9 sheet 4 of 8

UNITED STATES - DEPARTMENT OF THE INTERIOR - BUREAU OF RECLAMATION - UPPER MISSOURI REGION

SOIL LABORATORY - MILES CITY, MONTANA

UNIT SHY/6 PROJECT

SOIL SCIENTIST [illegible] LOCATION - SECTION 6 T. 4S R. 45E DATE 11/77

LAB NO.	PROFILE NO.	DEPTH METERS	TEXTURE FIELD	TEXTURE LAB	pH 1-5	pH $CaCl_2$	SET. VOL. ml	EC 1-5	EC SAT. EXT.	FRAG. HYD. COND. 8 hr. in./hr.	FRAG. HYD. COND. 24 hr. in./hr.	SODIUM ABSORPTION RATIO TSC me/l	SODIUM ABSORPTION RATIO Cat.Mg. me/l	SODIUM ABSORPTION RATIO SAR	GYP. REQ. me/100g	PARTICLE SIZE PERCENTAGE SAND	PARTICLE SIZE PERCENTAGE SILT	PARTICLE SIZE PERCENTAGE CLAY	HCL	%
9	208	0-.30	CL		8.0		22	5.20 0.70	4.0	0.52	0.42								+	
	209	.30-.91	CL		7.5		27	5.20 0.70	3.4	0.13	0.10								++	
	210	.91-1.2	CL		7.1		26	6.40 0.90	6.0	0.24	0.20								++	
	211	1.2-1.7	L		5.6	5.4	29	14.40 3.00	10.8	2.72	8.00+								−	
10	212	0-.30	CL		7.7		22	4.60 0.62	3.2	1.20	1.72								+	
	213	.30-.76	<CL		8.0		19	4.00 0.52	3.7	0.36	0.33								+	
	214	.76-1.4	L		8.5		18	5.20 0.70	6.0	0.72	0.76								+	
	215	1.4-2.0	VFSL		7.9		17	16.00 3.60	14.0	0.72	0.78								+	
	216	2.0-2.6	VFSL		8.3		18	10.20 1.85	13.0	0.64	0.64								+	
	217	2.6-3.0	CL		8.1		19	10.50 1.90	20.0	0.43	0.38								+	

UNITED STATES - DEPARTMENT OF THE INTERIOR - BUREAU OF RECLAMATION - UPPER MISSOURI REGION

SOIL LABORATORY - MILES CITY, MONTANA

UNIT SHY/6 PROJECT

SOIL SCIENTIST [illegible] LOCATION - SECTION 6 T. 4S R. 45E DATE 11/77

LAB NO.	PROFILE NO.	DEPTH METERS	TEXTURE FIELD	TEXTURE LAB	pH 1-5	pH $CaCl_2$	SET. VOL. ml	EC 1-5	EC SAT. EXT.	FRAG. HYD. COND. 8 hr. in./hr.	FRAG. HYD. COND. 24 hr. in./hr.	SODIUM ABSORPTION RATIO TSC me/l	SODIUM ABSORPTION RATIO Cat.Mg. me/l	SODIUM ABSORPTION RATIO SAR	GYP. REQ. me/100g	PARTICLE SIZE PERCENTAGE SAND	PARTICLE SIZE PERCENTAGE SILT	PARTICLE SIZE PERCENTAGE CLAY	HCL	%
11	218	0-.30	CL		7.4		21	5.80 0.80	5.5	2.24	8.00+								+	
	219	.30-.61	CL		7.7		24	5.60 0.77	4.5	0.26	0.20								,+	
	220	.61-1.1	>CL		8.4		29	16.00 3.60	21.5	0.05	0.03	215.0	125.0	11.25	-9.6				#	
	221	1.1-1.5	>CL		8.3		37	19.00 5.80	14.0	0.05	0.04								#	
	222	1.5-2.1	LFS		8.8	8.2	18	9.80 1.70	20.0	1.52	1.80								##	
12	223	0-.46	CL		7.3		22	4.80 0.65	4.1	0.90	5.16								,+	
	224	.46-.76	CL		8.2		22	2.60 0.32		0.40	0.40								#	
	225	.76-1.2	FSL		8.6	7.4	25	3.00 0.38		0.62	0.84								,+	
	226	1.2-1.7	FSL		8.7	7.4	22	3.00 0.38		1.28	2.28								#	
	227	1.7-2.1	FSL		8.8	7.4	26	3.80 0.50		1.04	1.60								#	
	228	2.1-2.4	CL		8.1		28	7.60 1.25	6.0	0.35	0.31								#	

Table 9 sheet 6 of 8

UNITED STATES - DEPARTMENT OF THE INTERIOR - BUREAU OF RECLAMATION - UPPER MISSOURI REGION

SOIL LABORATORY - MILES CITY, MONTANA

UNIT SHY/6 PROJECT

SOIL SCIENTIST [illegible] LOCATION - SECTION 6 T. 4 S R. 45 E DATE 11/77

LAB NO.	PROFILE NO.	DEPTH METERS	TEXTURE FIELD	TEXTURE LAB	pH 1-5	pH $CaCl_2$	SET. VOL. ml	EC 1-5	EC SAT. EXT.	FRAG. HYD. COND. 8 hr. in./hr.	FRAG. HYD. COND. 24 hr. in./hr.	SODIUM ABSORPTION RATIO TSC me/l	SODIUM ABSORPTION RATIO Cat.Mg. me/l	SODIUM ABSORPTION RATIO SAR	GYP. REQ. me/100g	PARTICLE SIZE PERCENTAGE SAND	PARTICLE SIZE PERCENTAGE SILT	PARTICLE SIZE PERCENTAGE CLAY	HCL	%
13	229	0-.30	>L		7.5		22	3.00 0.38		3.04	6.40								+	
	230	.30-.91	<CL		7.2		22	4.80 0.65	4.5	1.20	1.44								#	
	231	.91-1.5	CL		7.7		20	3.60 0.46		0.64	0.68								#	
14	232	0-.30	CL		7.6		21	4.00 0.52	3.8	0.32	0.24								+	
	233	.30-.91	CL		7.2		24	11.00 2.00	11.0	0.21	0.24								#	
	234	.91-1.5	CL		7.2		26	13.00 4.10	9.5	0.17	0.17								#	

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
BUREAU OF RECLAMATION
BISMARCK, NORTH DAKOTA
SOIL ANALYSIS DATA SHEET

Date Received 7-21-78
Date Reported 8-28-78

AREA: Sky Lo Study Site INVESTIGATOR: Toni Fiechtl SECTION: 6 TOWNSHIP: 45 RANGE: 45E

Laboratory Number	Sack Number	Boring Number	Depth in feet	Text. Field	Frag. Hyd. Cond. 2 Hr. in./Hr.	4 Hr. in./Hr.	24 Hr. in./Hr.	Sat. Vol. ml.	pH @ 25 1:5	B	Cd	Cu	Fe	Hg	Mn	Pb	Se	Zn	ECe @ 25°C	SAR	M.R. % 15 BAR	VCo. 2-1 (mm)	Co. 1-.5 (mm)	Med. .5-.25 (mm)	F .25-.10 (mm)	VF .10-.05 (mm)	Sand 2 (mm)	Silt .050 (mm)	Clay .002 (mm)	Lab. Text. Class
11,894	1	DH 78-101	3'-24"		*3/4	0.04	0.04	31.	7.3	1.8	0.16	8.2	146		14.6	11.0		8.4	7.0		14.4						10.4	48.7	40.9	SIC
5	2		24'-44'		*1/5	*1/4	*1/4	153.	7.9	0.8	0.12	10.8	240		7.4	21.2		17.9	4.9	20.	18.1						13.2	32.7	54.1	C
6	3		44'-69'		*1/10	*1/10	*1/4	162.	9.9	0.1	0.08	4.4	130		7.8	6.8		9.0	1.7	17.	21.5						13.1	57.9	29.0	SICL
7	4		69'-94'		*1/10	*1/5	*1/4	127.	9.9	0.1	0.06	2.2	190		12.6	5.0		6.8	1.7		26.7						17.7	57.8	24.5	SIL
8	5		94'-119'		*1/10	*1/5	*1/4	177.	10.0	0.0	0.04	1.4	126		10.0	3.0		5.4	1.1	11.	30.6						30.6	47.8	21.6	L
9	6		119'-144'		*1/10	*1/5	*1/4	191.	10.1	0.3	0.04	2.0	112		11.0	3.4		6.2	1.2		31.0						39.5	39.9	20.6	L
900	7		144'-167'		*1/10	*1/5	*1/4	176.	9.9	0.2	0.04	1.6	108		14.6	2.8		5.6	1.0	21.	27.2						43.7	34.1	22.2	L
1	8		167'-195'		*1/10	*1/5	*1/4	135.	10.0	0.0	0.02	0.8	94		7.4	6.8		3.2	1.0		19.5	0.2	2.5	2.4	47.9	19.8	72.8	11.9	15.3	FSL
2	9		195'-220'		*1/10	*1/5	*1/4	105.	9.9	0.1	0.04	0.8	72		5.0	3.6		2.6	2.2		13.1	0.1	1.5	3.7	66.5	7.2	80.0	9.1	10.9	FSL
11,903	10		257'-270'		<0.01	0.02	0.02	26.	9.4	0.0	0.04	1.0	98		9.8	9.0		3.8	1.7		7.33						31.7	58.2	10.1	SIL

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